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A Profession Without Unity—An Editorial

By HERBERT J. GILKEY
Second Vice President of the Society

In these strenuous times the engineering profession is confronted with a variety of complex problems many of which can be neither side-stepped nor deferred; they will be answered either *by us* or *for us*.

We talk of an engineering profession; of its relationship to a post-war world; of all manner of problems regarding it, but, after all, what is this profession? Who and what is an engineer? The 1940 S.P.E.E. report on Aims and Scope (Vol. XXX, No. 7, March 1940, p. 558) probably went as far as it is possible to go at present when, after outlining the great diversification and range of engineering activity, concluded that ". . . the *engineering profession* clearly cannot isolate itself from this complex of men and functions as a well-defined caste, it may be said to exist as a vaguely bounded nucleus within a much larger enveloping group which we may call the *engineering fraternity*."

While true, and therefore academically satisfying, this statement gets us nowhere in our attempts to solve some of the problems now being pressed upon us. Whether we be members of a *profession* or a *fraternity* matters little; we are members of an inarticulate group, one without a common tongue. Doctors and lawyers are articulate; we envy them, assuming that we need but do as they have done to attain an equally satisfactory solution to our problem of professional self-expression. Such unwarranted assumptions on our part are at variance with the engineer's alleged method of "looking his facts in the face." Professional groups such as those of law and medicine are relatively homogeneous, virtually every member of the entire profession performing purely personal services at a common level of professional stratification. There exist within such a group few problems comparable to: the employing engineer vs. the employee engineer, the designing and inspection engineer vs. the constructing and contracting engineer; the salaried vs. the private-practice engineer. There is no problem of professional vs. sub-professional services involving the promiscuous intermingling of recent graduates on their way up and mature men who are permanently established at a low engineering level. Probably most of the complicating elements within an engineering group are inherent and it is unlikely that engineering will ever be able to achieve neat segregations comparable to the clean-cut differentials between doctors and related practitioners such as internes, nurses, attendants, medical technicians, nutritionists, ambulance drivers, pharmacists, druggists, chemists, bacteriologists and veterinarians. To be at all comparable in scope to engineering, medicine would have to embrace

everything from the delivery of a baby to the disposal of a carcass, from the manufacture of drugs and instruments to the performance of a tonsillectomy on a giraffe.

Aside from the great diversity within a curricular engineering group there are very great differences in origins, backgrounds, economic status, outlook and interests between such major curricular groups as electrical, mechanical and civil engineers. Moreover, the whole trend in engineering appears to be toward the assumption of ever greater and more complicating diversification; from the field of design and construction the engineer is being urged and virtually forced into the fields of finance, management, economics and politics. Obviously then, the engineer's problems of professional unification are complicated ones.

The failure of engineering thus far to have attained a reasonably satisfactory professional status is due much more to the complexity of the problem than to a lack of well directed effort or a failure to recognize a need. Far from being individualists and hermits, engineers are really quite gregarious; they are probably greater "joiners" than are either their legal or medical contemporaries. On the whole, the engineer of today has a rather highly developed professional self-consciousness but it is directed to the several founder and related societies not one of which can speak for the engineering *fraternity*. It is this fact that leaves the "profession" a lamb at large without a spokesman in an era of organized groups (one might say wolves) among which selfishness and piracy are rampant.

In spite of the fact that the ideals of a professional group worthy of the name are directed exactly 180 degrees away from those of the present day union in their outlook and attitude toward the public welfare, the fact remains that even now junior members of the engineering profession are being forced to unionize because otherwise they have no legal voice. We of the engineering fraternity have before us a choice between *unification* and *unionization;* for many of our constituency there is apparently no other alternative. This is but one of the questions confronting us but it is certainly one that calls for the best we have to offer toward a prompt solution; we supply an answer or it will be supplied for us.

If we propose to continue to perform engineering functions under engineering auspices it is up to us to supplement the excellent professional organizations now functioning effectively within their several fields by the addition of a nonrestrictive overall framework, an umbrella, under which all can function as a unit without any attempt, however, to alter the individuality or freedom of action of any professional group within its normal sphere of operation.

As pointed out by President Doherty in his letter of September 28, 1943 (November issue of the Journal, p. 205), the E.C.P.D. constitutes the latest and to date the most promising attempt to provide the type of overhead organization required if professional unification is to be achieved. This attempt can succeed only in so far as it secures the recognition, acceptance and support of the individual members of the engineering profession and it is there that the S.P.E.E. enters the picture in a most altruistic role.

Working through the S.P.E.E. membership, the engineering teachers, the

national professional organizations have been able to augment the effectiveness of their activities greatly during the past twenty years by tapping the interests and securing the support of the appropriate curricular groups of engineering students. By capitalizing on past experiences and using essentially the same approach it should easily be possible to extend the interest and loyalty of upper-class engineering students to embrace not only their respective curricular engineering groups but to include an interest in and whole-hearted support of the overall cover that must embrace the entire profession.

This assignment is tailor made for the Sections and Branches of the S.P.E.E. It is the local S.P.E.E. membership which can, if it will, inject overall engineering esprit de corps into the members of the oncoming generation of engineers.

It is with such matters in mind that a meeting under the auspices of Sections and Branches is being scheduled for the forthcoming Cincinnati convention, June 22–25, and it is here urged that all members of the Society give careful advance thought and study to these problems with a view to making constructive contributions to the discussions of next June.

The A.S.T.P. Situation

By ROBERT E. DOHERTY
President of the Society

The country rushed into A.S.T.P. on a grand scale, and being in, immediately rushed out. Why? Does this extraordinary phenomenon represent a blunder of the War Department or an unavoidable war casualty? Why didn't the engineering profession or the S.P.E.E. or somebody do something about it? These questions have been in the minds of many who carry responsibility in engineering education, and indeed have given rise to pointed expression and suggestions from some to the officers of the Society.

I certainly do not know the answers, but I do have basis for one or two observations.

At bottom seems to be the fact that the supply of manpower for the Army did not turn out as planned. The reason the supply did not turn out as planned was the inability of Selective Service to deliver the personnel as scheduled; and this inability, it seems, was due largely to the reluctance of Local Boards to draft fathers, although it is true that these Boards faced at the same time the necessity of other deferments, as in agriculture and industry. As far as I can find out, this is the explanation of why A.S.T.P. plans went awry.

Whether this was inevitable, I will not venture to answer. I can only say that in my opinion the questions of policy on which the situation turned were so deep seated as to be beyond the pale of the War Department in the face of its commitments, or of Selective Service Headquarters or the War Manpower Commission. Most certainly they were beyond the pale of the S.P.E.E. These questions, it seems, could be settled only at the level of the President and Congress, and whether for good or ill they have at least temporarily been settled.

Whether these questions will stay settled is highly uncertain. There is not sufficient manpower to go around. The review of physical standards of the Army did not provide relief by making eligible a significant number of men who had been classified as 4-F. The reduction of civilian deferments in engineering colleges from approximately 40,000 to 10,000 was a mere gesture so far as the total shortage was concerned, yet in the opinion of many informed people outside the Army and Selective Service it was a serious error from the point of view of national welfare. The wisdom of the present agricultural and industrial deferments is being challenged, and Selective Service is increasing its pressure for the draft of fathers. Involved here are the demands of total war impinging upon the meagre remains of undrafted manpower. The forces involved—both political and emotional—are tremendous. We cannot have the cake and eat it, and the President and

Congress must decide which we are to do. What the final answer will be and whether it will affect what is left of A.S.T.P., is at this moment anybody's guess. Maybe the war will be over some day!

In any case, the officers of S.P.E.E. will continue to do whatever seems to them, after careful study, in the best interests of the country and engineering education, and to this end they invite informed counsel.

The University of Cincinnati and Its College of Engineering and Commerce

By CLYDE W. PARK
Professor of English

At the present writing, for reasons that every delegate to the convention will appreciate, the host institution finds itself outwardly changed. The transformation, of course, is typical, and the activities of the University and its various departments may be said to represent the kind of tasks with which American colleges in general are now occupied. Here as elsewhere, the classrooms are filled with men in uniform, and the word "campus" has returned to its ancient Roman meaning of a field for martial exercise.

The new training schedule, it should be noted, has not entirely supplanted the regular one, but supplements it and is dove-tailed with it. Although civilian enrollments are smaller and classes are more accelerated, there is a substantial remnant of the pre-war program through which the University's traditions are being kept alive. In the new coöperative course in engineering for women there is also a hint of future developments in one phase of technical training.

To the visitor, even amid surface changes and distractions, the University of Cincinnati reveals a marked degree of individuality, the natural result of its origin and history. Shortly before the turn of the century Cincinnati was often referred to as the only American city that had built a railroad and established a university. Of these two very different forms of civic enterprise the university had been much the earlier to develop. In a monograph dealing with the history of higher education in Cincinnati President Raymond Walters has traced the growth of the University from the founding of the "Cincinnati College" in 1819. Of its presidents in that early period the first, Elijah Slack, had been vice-president of Princeton, and a later one, Dr. William H. McGuffy (1836–1839), had published the first four of the famous McGuffy Eclectic readers during his presidency. It was at this time too (1836) that a course in civil engineering, one of the first collegiate courses of the kind in America, was started at the Cincinnati College. The story of this pioneer institution, with its changing fortunes, reflects a strong community interest in classical education and a determination to do something about it. Logical expansion is seen in its affiliation with the Medical College of Ohio, through Dr. Daniel Drake and others, its development of a Law Department, made famous by Professors Timothy Walker and John C. Wright, and its fostering of an Astronomical Society under the leadership of Professor Ormsby M. Mitchell. When a generous bequest from Charles McMicken made possible

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in 1870, the establishment of a municipal university, it was logical that the newly formed institution should absorb the charter of the earlier Cincinnati College. This relationship and a suggestion of continuity are conveyed by the two founding dates of 1819 and 1870, which appear on the University's official seal.

As in most colleges other than those established under the Morrill Act, which were avowedly technical from the start, engineering courses at the University of Cincinnati began as adjuncts to the regular college of Liberal Arts. Such a designation, for example, as "Professor of Physics in charge of electrical engineering," was found in catalog statements as recently as 1905. The first professorship of engineering as such was an endowed chair of civil engineering within the College of Liberal Arts. One of this department's best remembered graduates is the late Joseph B. Strauss, class of 1892, who originated the Strauss type of trunnion bascule bridge and designed San Francisco's "Golden Gate" Bridge.

The gradual growth of the University as a whole included the addition of courses in mechanical, electrical and chemical engineering. So far as the technical divisions of the University were concerned this growth was greatly accelerated by an educational experiment which was begun in 1906, during the presidency of Dr. Charles W. Dabney. Under the leadership of the late Dean Herman Schneider a "coöperative course" in engineering was made available to a few students in mechanical, electrical and chemical engineering. These young men were divided into two "sections" and took turns attending college one week and working the next week as regular employees of industrial firms in Cincinnati. Since each student had an "alternate" who replaced him either at college or in industry, both the school work and the shop work were carried forward without interruption. Theoretical and practical training were coördinated in a planned sequence extending over a period of six years, half study and half "outside" work.

The success of the coöperative experiment was such that the College of Engineering entered upon a period of rapid expansion. Along with increased enrollment of students, additions were made to the number and types of cooperating firms and hence, to the variety of industrial experience. When civil engineering was offered on the coöperative basis (1909), employment was made available by railroads, construction companies and public service departments. The geographical radius of coöperative work was also increased.

Although the regular four-year course in engineering was continued, the students who preferred the coöperative plan were soon in the majority. As against 27 coöperative students in 1906, there were 106 regulars. The high figure for the latter group was 113 in 1907. From this point the numbers dwindled gradually, reaching 0 in 1920. In this same period the enrollment of "coöps" increased to 950.

Visible evidence of growth following the introduction of the coöperative course is found in the enlarged physical plant, including all of the buildings constituting the present engineering quadrangle. Inasmuch as only half of the students were attending college at one time the expansion in buildings and facilities was proportionately much less than would have been the case with full-time attendance. For more than fifteen years prior to the outbreak of World War II, the average enrollment was kept at a point somewhere between 1,800 and 1,900.

Space does not permit more than a brief mention of the increased range of interests, either directly connected or closely affiliated, which accompanied the expansion of the college. A division of Commerce, or Business Administration, on the coöperative plan was incorporated with the college of engi-

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neering. Coöperative courses, both in business and in chemical engineering, were opened to women as early as 1920. Closely affiliated with the older college was a department of architecture and a "School of Applied Arts." A department of aeronautical engineering and a division of "general" engineering became regular units of the College of Engineering and Commerce.

An incidental development paralleling the growth of the college has been the establishment of research laboratories, examples of which are leather research, conducted in a building presented to the University by the Tanners' Council of America, lithographic research, carried on for the Lithographic Technical Foundation, and "basic" or general research, conducted in a laboratory which was founded by the late Dean Herman Schneider. This last division also operates as a Graduate School of Applied Science. Some of the workers hold research fellowships which are maintained by the Stephen Wilder Foundation. The laboratory also provides coöperative training at the postgraduate level, with alternating six months periods of work experience in the research departments of various industrial corporations.

The Graphical Derivation of Alignment Diagrams from Network Charts. Quasi-Alignment Diagrams

By DOUGLAS P. ADAMS

Assistant Professor of Graphics, Massachusetts Institute of Technology

(The contribution of nomography to American engineering has been and is very great but its possibilities are much greater. This article is written for the engineer who appreciates nomography and who wishes to increase his knowledge and ability in that field. It does not purport to lay down many rules but rather sets forth a way of thinking about the subject which makes some of its more difficult aspects more readily available. The traditional resourcefulness of the practicing engineer will be required to understand and to apply its content most fully. The rigorous mathematical background underlying the material has been interpreted in practical terms.)

1. The Practical Value of this Subject for the Engineer.—It is especially appropriate in wartime for the engineer to minimize computations. The alignment diagram, popularly called the nomographic chart, has always been a favorite tool for this purpose in engineering but has not been available to those who were unfamiliar with its theory. The network chart, however (Fig. 1), is well known from secondary school to all persons in scientific work and to many others because it is a natural and easy way of expressing relations between three variables and can often quickly be extended to represent mathematical relationships between more than three variables. Unfortunately it lacks the open aspect, ready legibility and foolproof manner of operation of the alignment diagram and hence cannot be employed as quickly, accurately, nor by as numerous a class of persons as the alignment diagram. Hence a sound, direct method for carrying network charts into alignment diagrams has practical value.

2. A Comparison of Rectilinear Network Charts and Alignment Diagrams in Three Variables.—For convenience in this article we refer to the network and alignment figures as the chart N and the diagram A respectively. Assume that equation (1)

$$F(U, V, W) = 0 \tag{1}$$

can be put in the particular but very

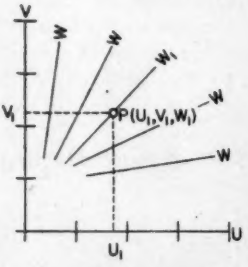

FIG. 1.

common chart form N of Fig. 1, when the W-lines, called the W-family o

W-set, is rectilinear. A random point P in the W-set always corresponds to a solution of (1) because it identifies compatible values of U, V, W in the manner indicated there. The more basic conception of such a chart, conveyed by Fig. 2, is that of three families or sets of lines. The process of identifying a solution in Fig. 2 is not one of reference over to axis scales, as in Fig. 1, but that of direct reading of set members. Assume that an alignment diagram A, Fig. 3, exists for (1).

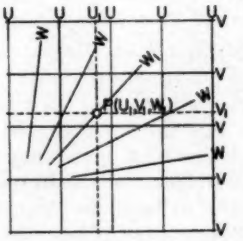

FIG. 2.

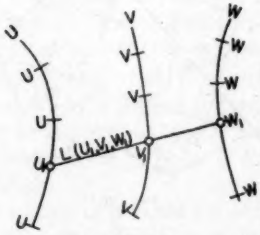

FIG. 3.

Here we find values of the variables represented as points on a curve rather than as lines of a set. The identification of compatible U, V, W values is done by writing down values of three points which lie on a line L rather than values of three lines through a point P. The chart N of Fig. 2 and the diagram A of Fig. 3 can accordingly be described as *dual* figures in point and line if, on proper selection of A, any property in point and line of one is reflected in the same property of line and point in the other.

3. The Principle of Duality.—This duality of point and line is more than a vague and curious property of these two figures. It is a basic relationship of extensive analytic power so common as to be almost inescapable in any penetrating geometric thought. Thus, in the elementary equation

$$A \cdot X + B \cdot Y = 1, \tag{2}$$

we observe that for fixed A and B, X and Y varying, we derive all of the points lying upon and thus defining a straight line with intercepts $1/A$, $1/B$; for fixed X and Y, A and B varying, we derive all of the lines lying through and thus defining a point with position X, Y. Thus the pairs A, B and X, Y, entering (2) symmetrically, yield figures which are dual in point and line. We emerge with the *Proposition I: A true dual to a network chart for (1) will be an alignment diagram for (1).*

*4. Construction of Dual Figures. Poles and Polars.**—There are numerous ways of constructing a dual for a given figure. One very good graphical method for the engineer employs a conic. It defines the *chord* joining the tangent points of two lines tangent to any conic C as the dual (with respect to C) of the *point* of intersection of those tangents, the dual line and point being known as polar and pole. Special properties of the conic now make it possible to define the line joining two poles as bearing to the point of intersection of their polars in like manner the relation of polar and pole. Readers to whom this subject is new

* Osgood and Graustein "Plane and Solid Analytic Geometry" is a good reference book for this and related subjects.

may enjoy testing graphically the proposition which makes this complete duality possible, namely, that the chords of a conic are concurrent when and only when they join tangent points of pairs of lines tangent to the conic from colinear points.

The subject of pole and polar has certain practical simplifications for the special conic known as the parabola. Figure 4. Let point F and line D be

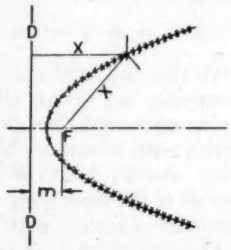

FIG. 4.

distant by m. The locus of points equidistant from F and D is a parabola with focus F and directrix D. With respect to a positive X-axis of symmetry and a Y-axis through the vertex its equation is

$$y^2 = 2mx. \tag{3}$$

The slope of the tangent at any point $Q(x_1, y_1)$ is given by

$$\lambda = \frac{m}{y_1}. \tag{4}$$

A line through the focus perpendicular to the axes is known as the latus rectum. Its length within the parabola is $2m$. The tangents at its extremities lie at $\pm 45°$. In Fig. 5(a), L is any line, T the tangent to the parabola parallel to L, Q the point of its tangency. Let M be a line through Q parallel to the axis, intersecting L in R. Place point P on M so that $\overline{PQ} = \overline{QR}$. Then P is the pole of L. P always lies on the opposite side of the curve from L. Figure 5(b) verifies graphically that this derivation agrees with the original one using tangents. A combination of Fig. 5(a) and equation (4) yields an easier method for getting the pole or polar. Since $\lambda_T = \frac{m}{y_1}$, $\lambda_N = -\frac{y_1}{m}$ where λ_N is the slope of the normal, a line through the focus perpendicular to the polar (see Fig. 6)

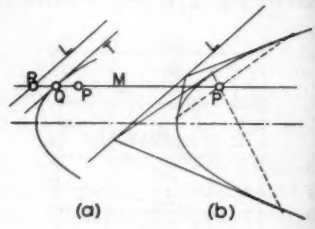

FIG. 5.

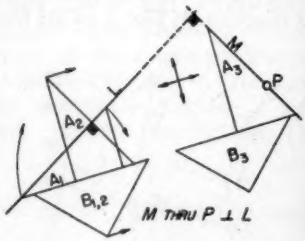

FIG. 6.

accordingly cuts the directrix at a height y_1, or at a point through which line M parallel to the axis and bearing the pole passes. Pole and polar cut this line equidistantly from the parabola along M. Figure 7 shows this method for deriving pole or polar, and hence for carrying any set of lines into the curve of points which is its dual. Thus the three sets of lines of a network chart can be carried into the three scales of an alignment diagram.

The nomographer will find it useful to know that the line from a pole to the geometric center of any conic cuts the latter at a point where the tangent to it is parallel to the polar. A second useful property can be stated as follows: Let O be the geometric center of the conic, P a pole and L its polar. Let OP cut the curve at T and L at Q. Then $\overline{OP}/\overline{OT} = \overline{OT}/\overline{OQ}$, or $\overline{OP} \cdot \overline{OQ} = \overline{OT}^2$. These properties are illustrated in Fig. 5(a) for the parabola, whose geometric center lies on the axis of symmetry infinitely far out. They also show that tangent line and tangent point are dual in any conic, being pole and polar. Again, they show that the pole of a diameter of a conic is at infinity and likewise the polar of the center of the conic. Further, for the circle, the pole will always lie on a line M through the center perpendicular to the polar. The points P and Q in which the pole and polar, or polar and pole cut line M can be found graphically as follows: Extend M through O. Let Q' be a point on M on the other side of O from Q and such that $\overline{OQ'} = \overline{OQ}$. Let T be the point of intersection of M and the conic and let OR be a line equal to OT and perpendicular to M. Then $Q'RP$ is a right angle.

The choice of a conic for obtaining a certain dual figure is a practical matter. The parabola is very useful, Fig. 7, although polars with slopes near zero become troublesome. (See later treatment.) It has the advantage over other conics in that the size of the dual figure is more often comparable to that of the given figure.

5. Alignment Diagrams from Simple Network Charts.—Assume two of the sets, such as the U-set and V-set of Fig. 2, to consist of two orthogonal sets or families of parallel lines. The points of the dual U' "curve" in a parabola to the U-set will accordingly all have the same ordinate and hence lie along the same straight line M_U parallel to the axis of the parabola. M_V will behave likewise and be parallel

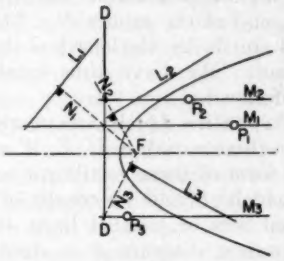

FIG. 7.

to M_U. If the U-set is uniformly spaced (that is if the U-scale on the "U-axis" of the network chart was uniform), the set will cut the line M_U at uniform intervals and create a uniform U-scale on the alignment diagram. V behaves similarly. In many cases, the W-scale of the alignment diagram can quickly be derived from the W-set by similar considerations but if necessary can be derived point by point by the method of Fig. 7.

We make the process for deriving this type of diagram more direct in several ways. Tilt the network chart at 45°, causing the U and V scales of A to pass through the ends of the latus rectum. Place N so that it "opens out" toward the vertex of the parabola and at such a distance that the U and V set lines furthest from the N-chart axes are tangent to the parabola. The tangency will occur at the ends of the latus rectum causing the U and V scales in A to *terminate squarely* on that line. Use a uniform scale change in U or V in N to give the latter a square shape, thereby placing the

origin on the extended axis of the parabola. The W-set in N will still be rectilinear and the U and V scales in A will now commence at the same distance from the latus rectum thereby *squaring* the further end of A. The length of the U and V scales of the rectangular diagram A will equal the diagonal of the square N. The base of A equals $2m$, the length of the latus rectum. We have thus established the following.

Proposition II: If a network chart N in three variables U, V, W assumes the form of three rectilinear sets two of which (U and V) consist of orthogonal sets of parallel lines, then an alignment diagram A (a dual of N) exists containing similar U and V scales and in which these scales can be made coextensive with the opposite sides of any rectangle. The points of the W-scale in A can then be found accurately by cross-alignment from the data of N or by the method of polar and pole (Fig. 8).

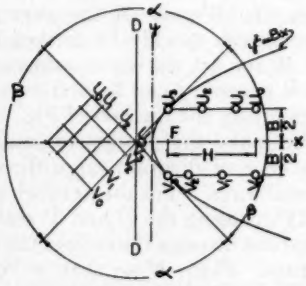

FIG. 8.

Our methods are extendable to compound network charts in more than three variables.

6. Rectification.—Network charts frequently have W-sets consisting in whole or in part of *curves*. The methods described must then be preceded, where possible, by some process of rec-

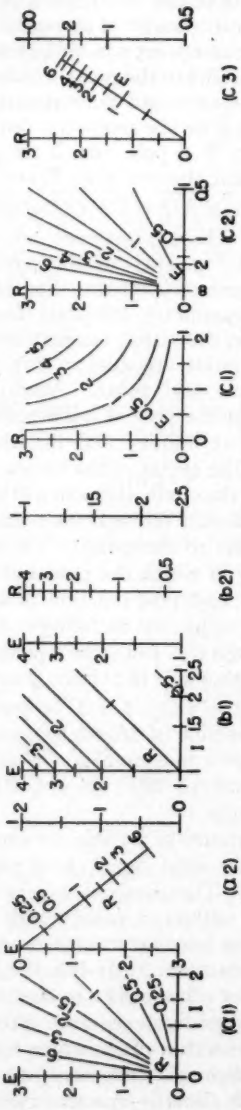

FIG. 9.

tification which will yield a W-set consisting of straight lines. Another way of treating the problem is described later. The rectification can sometimes be achieved merely by interchanging the roles of U or V and W as the family parameter for the third set. Thus in the equation $E = I \cdot R$, changing the family parameter from E to R rectifies the chart as shown in Figs. 9(c_1) and 9(a_1). Figure 9(c_1) could also be rectified by plotting reciprocal coordinates for I or R, as shown in 9(c_2). A logarithmic form appears in 9(b_1). Figures 9(a_2), 9(b_2), 9(c_3) are the corresponding alignment diagrams. Experience shows that many of the W-sets of curves arising in practice can be straightened out in one of these ways, or by arbitrary U or V distortions, or both. Empirical data can frequently be put into alignment diagram form in this way.

FIG. 9.

7. Empirical and "Rule of Thumb" Methods. W-scale Outside the Diagram.—Empirical charts have done such very great harm to nomography that it would be unfair to the subject not to put them in their place. An empiricist is one who wishfully believes, with no basis in theory, that a nomographic chart can be made for an equation by placing and graduating certain scales to his liking and adjusting the alignment property to get the rest of the scales. He is to be distinguished from the "rule of thumb" or "shortcut" nomographer whose methods have at least some basis in theory and chiefly lack flexibility. The empirical nomographer does not hesitate to extend Proposition II to any three-variable equation whatsoever. He does not bother to examine the aspect of the network chart resulting from his choice of U and V variables to see if the W-set is rectilinear but simply creates convenient U and V scales on the sides of rectangle A, takes mean values of points in W obtained by several cross-alignments, and weights a curve through these points. He bends his U and V scales at will to give greater "accuracy" and then proves to himself that the chart "works" by checking with values close to those used in derivation. Readers quickly detect errors in the chart and attribute its unreliability to the broad subject of nomography. The "rule of thumb" nomographer usually uses more carefully the proposition we have established above and related material gleaned from experience which is apt to be so special and inflexible that he is tempted to use a few empirical "aids." He would frequently be at a loss in the following situation: If the W-set appearing in N consists of lines with slopes in quadrants α, Fig. 8, the lines M will all lie within the rectangle A_R and so will the W-scale. If the W-set consists of lines with slopes lying entirely in quadrants β, however, the lines M and the W-scale will lie entirely *outside* the convenient rectangle A_R. The "rule of thumb" nomographer may not know how to reduce his chart to convenient form. Figure 8, however, yields the following:

Procedure I: If the lines of the W-set have slopes in quadrants β, rotate N through 90°, placing them in α. The U and V scales of A will then be interchanged, the direction of one of them will be reversed, and the W-scale will lie within the rectangle A_R.

Procedure II: If the lines of the W-set have some slopes in quadrants α and some slopes in quadrants β, complete the diagram for those in α. Rotate N through 90° and make a new diagram for those which were in β. These two diagrams can be superposed

using the identical U-scale. There can then be a V-scale up and a V-scale down on opposite sides of the same scale stem and respectively applicable to certain ranges of W.

These methods work well. They can be reduced to "rules of thumb" by persons so inclined but it is hoped that the value of working from drawings such as Fig. 8 has been established.

8. Graphical Transformation of Alignment Diagrams.—Nomography for the engineer is concerned with the creation of alignment diagrams to specified size and proportions. We take for granted the value to him of graphical methods in doing this work. Clearly the above discussion of the general dual representation of network chart and alignment diagram in the conic can be applied very extensively, Fig. 8 and its Proposition being a proper but limited illustration. Thus chart N implies a variety of forms of dual diagrams A when the position RN of N with respect to the conic is varied. If one of these diagrams, A_1, happens to be a known form and another, A_2, happens to be a desirable form, we have chanced upon a means of passing between given and desirable forms, that is, through C, RN_1, N and RN_2. Our real problem then becomes that of finding a general method of passing in this way from known to desirable forms of the diagram. Here we are free to choose

(1) C, the conic used to derive the chart from the diagram.
(2) RA_1, the position of A_1 with respect to C.
(3) N, the form of the network chart, since it can still be varied after derivation.
(4) C', the second conic which will be used to derive A_2 from N.
(5) RN, the position of N with respect to the conic.

Let A be a point in plane α and P a point outside plane α and plane α'. Draw ray R from P through A cutting plane α' in A'. Then A' is said to be the central projection of A on α' with respect to P. If B' is the central projection from P onto α' of a second point B in α, then line $A'B'$ is the central projection of line AB. Let D be a rectilinear network chart or an alignment diagram in α and D' the central projection of every point and line of D into α'. Since straight lines, and hence colineations also, are preserved under this central projection, D' will also be an accurate rectilinear network chart or alignment diagram respectively in α'. We accept the statement that every central projection preserves a tangency between a line and a curve and carries a conic into a conic. Assume that A and A' are two alignment diagrams for the same equation such that we can establish the central projection in space which takes diagram A in plane α into diagram A' in plane α'. Create in α a conic C and the rectilinear network chart N in α dual to A. Project C and N into C' and N' in α'. Then N' is a rectilinear network chart dual to A' in α' through the conic C'. Note that C was chosen at random and that N' is a network chart derivable from N. Hence we have the

Proposition III: A form A' of alignment diagram related to a given form A by a central projection can be obtained in a variety of ways by passing through related network charts N and N' respectively dual to A and A'.

The variety of ways mentioned is so very great that the form A' can often be obtained graphically from A by the

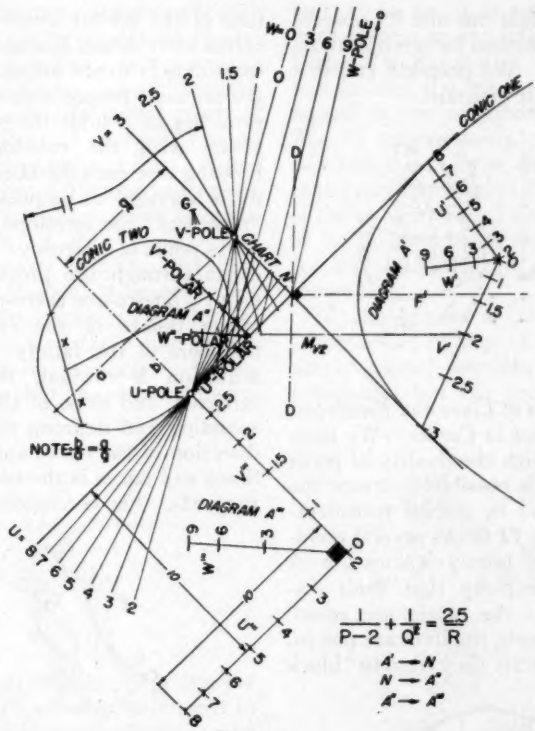

FIG. 10.

direct use of the material on pole and polar which we have given above together with properties of conics and the theorems of plane geometry. As an illustration, let A', Fig. 10, be a common type diagram for the equation $\frac{1}{P-2}+\frac{1}{Q^2}=\frac{2.5}{R}$. We wish to construct a new diagram A''' such that the new U and V scales lie at 90° and each is 10 inches long. It is known that this change could be achieved by a central projection. The graphical solution appears in Fig. 10 with as many of the steps as possible indicated there. The considerations mentioned above were the only ones used.

QUASI-ALIGNMENT DIAGRAMS

9. Meaning of the Term Quasi-Alignment Diagram.—The alignment diagram has come to be thought of as employing or relying upon two procedures—the *running of a straight line* across its surface and the reading of its scales by observing where they were *cut by the straight line.* This is true even although the diagram consists of one or more networks. Figure 11 is a chart in four variables illustrating these properties. The type of chart we are about to derive is closely related to such an alignment diagram except that a solution is found by

drawing a straight line and by observing *tangency relations* between it and a set of curves. We properly call it a quasi-alignment diagram.

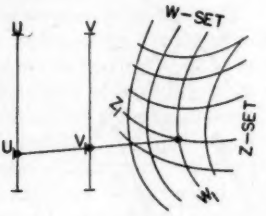

FIG. 11.

10. Families of Lines and Envelopes. Duality Applied to Curves.—We have dealt above with the duality of point and line. It is possible to create the dual of a curve by similar considerations. Figure 12 shows several members of a set or family of lines L with the family property that their distances r from the origin are equal. The more densely the lines are put in, the more perfectly they seem to "block

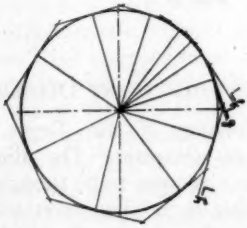

FIG. 12.

out" a curve, called the envelope of the family, which in this case is a circle of radius r. On a member L_θ of the set, the particular segment which "represents" the circle for a short distance is the portion included between the two family members L_f and L_h on either side of L_θ which most nearly coincide with L_θ. As additional members of the set are drawn and it becomes more dense, L_f and L_h approach more closely to one another and to L_θ, the segment becomes shorter and approaches as a limit its point of tangency with the envelope. In the limiting case each member of the family is assumed to be present and will "represent" the envelope at and only at its point of tangency. Thus there exists through the property of tangency a one-to-one correspondence between points of the envelope and members of the family. The representation is mutual, the point of tangency and slope of the line corresponding and defining the point and direction of the curve and vice versa. Since any curve is the envelope of its tangents, this correspondence exists

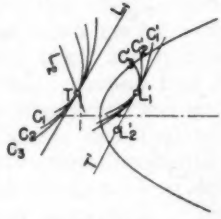

FIG. 13.

between the points of every curve and the family of tangents to the curve and each can be employed to represent the other.

Let curve C be represented by its points T and let T'_θ be the line dual to T_θ with respect to a conic S. The lines T' will define a curve C', their envelope, dual to C in S. The point of tangency L'_θ of T'_θ to C' will have L_θ as its dual line with respect to S. In Fig. 13, we verify these ideas graphically. We observe line L_1 tangent to curves C_1, C_2, C_3 at point T, and the dual curves C_1', C_2', C_3' with respect to the curve S constructed by

the laws of duality. Line L_1 through point T represents the curves at that point, point T on line L represents the curves on that line. Line T' through point L'_1 represents the dual curves at that point, point L'_1 on line T' represents the curves on that line. A line L_2, passing through T but bearing no special relation to the curves, becomes a point L_2' on T_1', etc.

11. The Inverse Dualities of Curvature and Arc Length.—Consider a set of equal circular segments C_1, C_2, C_3 of varying radius and their dual figures C_1', C_2', C_3' in the parabola.* Figure 14. Observe that the dual segments

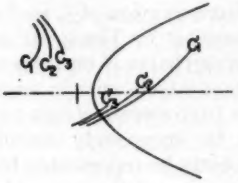

FIG. 14.

are unequal in length. The sharper curvature of C_1, causing its tangent to swing rapidly, has accordingly caused a rapid passage of the poles of its tangents across successive M-lines and simultaneous rapid changes of the distance of tangent and hence of pole from the curve. In the limiting case where C is a straight line of zero curvature the entire dual curve is a point possessing zero length and infinite curvature. We can present the basic picture in the following way. Let C be a segment of a smooth curve in a locality in which none of the tangents to C pass through the geometric center of a given conic. Let T be a tangent to the curve in the locality and let C' and T' be the dual curve and point with respect to the conic. Then the flatter C is, the shorter and sharper C' will be and the more closely C' will remain in the neighborhood of point T'. In other words, the sharpness and smallness of the arc length of C' in the neighborhood of T' is a measure of the straightness of C in the vicinity of its tangent point and conversely. See Fig. 13 for further graphical corroboration.

12. Application to Quasi-Alignment Charts.—Let N, Fig. 15, be a network chart in which rectification has been substantial but not complete. Only

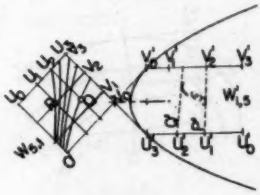

FIG. 15.

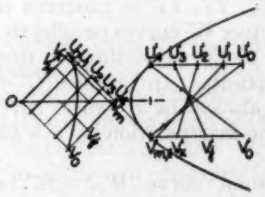

FIG. 16.

five members of the sets W and W' have been shown. Let A be the dual alignment diagram obtained from N by the above methods. The curves W' are now seen to be short arcs, their shortness and sharpness depending upon the degree of rectification which was achieved in N for their duals. Since W_3 is a straight line, W_3' is a point. A point P on W_P in N implying a solution $U_PV_PW_P$ appears as a

* These segments were intentionally drawn in such positions that their tangents all lie in quadrant α Figure 8.

line P' in A cutting the U' and V' scales at U_P' and V_P' and lying *tangent* to the short arc W_P'. The property of tangency is due to the fact that point P represents curve W_P in N and *line* P' represents the dual curve W_P' in A. The characteristics of this W' set are both *position* and *direction*. Interpolation can be carried out by eye on such a diagram using the principle that one of the characteristics of a solution U_1', V_1', W_1' is the *direction* $U_1'V_1'$ on the chart. Thus, let W_1', W_2', W_3', W_4' be reasonably close, consecutive curves of a W' set and T' a line of colineation. Figure 17. Let

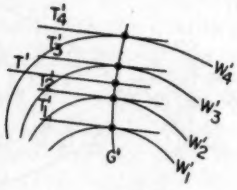

FIG. 17.

T_1', T_2', T_3', T_4' be tangents to their respective W' curves parallel to T' and let G' be the curve through these tangent points. In practice G' will almost always be a gentle curve permitting interpolation by eye along its path.

A dual curve W_P' can be constructed by observing that the points of W_P lie on U and V lines in N. The lines cut the diagonal of N at distances which are directly transferable to the U' and V' scales. Figure 8 and discussion. The dual of each such point of W_P is a tangent line to W_P' determined by these U' and V' values. W_P' can thus be blocked out as closely as desired. Figure 16. The U' and V' values determining the tangent lines to W_P' could also simply be read off of N. Hence we have

Proposition IV: If a network chart N in three variables U, V, W assumes the form of two orthogonal rectilinear sets (U and V) and a third set W of curves, a quasi-alignment diagram A dual to N exists containing similar U and V scales and in which these scales can be made coextensive with the sides of any rectangle. Any member W_1' of the set of curves dual to W can be found as the envelope of the lines in A joining U' and V' values determining points on W_P in N. The degree of rectification of W_P in N will determine the shortness and sharpness of the curve W_P'.

By considerations paralleling those of the latter portion of 7, we have also

Proposition V: The great majority of network charts N on perpendicular U, V axes which arise in engineering practice from *empirical data* and which cannot be completely rectified can conveniently be represented by simple quasi-alignment diagrams of desired rectangular aspect.

Maximum rectification in N is recommended but is not necessary.

If either or both of the U and V sets in N are not rectilinear, they can likewise be represented, simultaneously with W, by sets of U' and V' curves in A dual to their sets in N. A solution on such a diagram is found by

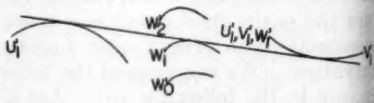

FIG. 18.

observing which member of the W' family is tangent to the common external tangent of the U' and V' members. Figure 18.

A further relationship here should be noted. Figure 19. Along a W'

curve, W' is constant. Let U' be the independent variable, then V' is dependent and will lie at the intersection with the V' scale of a line from U' tangent to W'. Each value U_1' implies a different point of tangency on W_1' and the W_1' curve could be graduated in the values of U'. If each

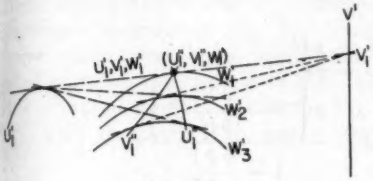

FIG. 19.

W' curve is so graduated for U_1', a U_1' curve is defined, U_1'', upon the W' set. The $U''W'$ net plus the V' curve now give a new type of chart which can be used by constructing a tangent to a W' curve at the point where it is cut by the U'' curve and observing where this tangent line cuts the V' scale or is tangent to a V' set member. A second similar family V'' can be constructed on the W' set creating a true network chart there designated $W'U''V''$. If U' or V' sets of curves exist, corresponding charts can be made for them, designated in the latter cases as a $U'V''W''$ network chart and a $V'U''W''$ network chart. The ability to vary the position and type of chart or diagram or combination adds greatly to the facility of the nomographer.

13. Matrix Form of the Quasi-Alignment Diagram.—Assume that an equation

$$F(U, V, W) = 0 \tag{1}$$

can be put in the form

$$\begin{vmatrix} U_x & U_y & 1 \\ V_x & V_y & 1 \\ W_x & W_y & 1 \end{vmatrix} = 0. \tag{2}$$

where we have, Condition One, that $U_x, U_y, V_x, V_y, W_x, W_y$ are functions of their respective capital letter variables only. Interpret $X_U \equiv U_x$, $Y_U \equiv U_y$, as parametric equations in U of a U-curve, defining by these X and Y coördinates the location of a particular value of U on this curve, and draw the curve. Draw V and W curves likewise. If U_1, V_1, W_1 satisfy (1), we have

$$\begin{vmatrix} X_{U1} & Y_{U1} & 1 \\ X_{V1} & Y_{V1} & 1 \\ X_{W1} & Y_{W1} & 1 \end{vmatrix} = 0. \tag{3}$$

Recall that the equation of a line through two points

$$\frac{x - x_1}{y - y_1} = \frac{x_2 - x_1}{y_2 - y_1} \tag{4}$$

can be put in the form

$$\begin{vmatrix} x & y & 1 \\ x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \end{vmatrix} = 0. \tag{5}$$

Hence (3) expresses the fact that the three points U_1, V_1, W_1, on their respective curves, are colinear. Since U_1, V_1, W_1 was any solution of (1), the above interpretation and drawing yields an alignment diagram for (1) and is a commonly accepted method for so doing. Condition One, however, frequently cannot be satisfied.

Since equations (1) arising in practice can in general be plotted as network charts in the form required for Proposition 5, and hence give rise to quasi-alignment diagrams as in Figs. 15 and 16, it is to be expected that a determinant form of (1) can also be derived which would give rise to the same figure. Briefly, it will be found that the properties of (1) can indeed

be expressed in the form *

$$(6)\qquad \begin{vmatrix} 0 & uU & 1 \\ B & vV & 1 \\ \dfrac{B}{1-\dfrac{v}{u}\dfrac{\partial V}{\partial U}} & \dfrac{v\left[V-\dfrac{\partial V}{\partial U}\cdot U\right]}{1-\dfrac{v}{u}\dfrac{\partial V}{\partial U}} & 1 \end{vmatrix} = 0.$$

Here we have

$$(7a)\qquad X_U = 0 \qquad\qquad Y_U = uU$$

$$(7b)\qquad X_V = B \qquad\qquad Y_V = vV$$

$$(7c)\qquad X_W = \frac{B}{1-\dfrac{v}{u}\dfrac{\partial V}{\partial U}} \qquad Y_W = \frac{v\left[V-\dfrac{\partial V}{\partial U}\cdot U\right]}{1-\dfrac{v}{u}\dfrac{\partial V}{\partial U}}.$$

In (7c), we have

$$(7c)\qquad X_W = X_W(U, V, W); \qquad Y_W = Y_W(U, V, W)$$

and hence Condition One is not satisfied.

Let $W = W_K$, assume $U = U_{K1}$ and compute $V = V_{K1}$ from (1). It will be found that the line of colineation through the points U_{K1} and V_{K1} on the U and V scales is *tangent* to the curve $W = W_K$ at the point on it derived by the substitution of U_{K1}, V_{K1} and W_K into (7). Thus when (1) is put in the form (6) a quasi-alignment diagram is obtained which is identical in form with that of Figs. 15 and 16. If the disposition of the U and V scales and W-set is not convenient, it can be made so by manipulation of (6) or of its dual network chart N as discussed in connection with Fig. 8.

A diagram based on Condition One is almost always superior to one based on the quasi-alignment form (6). The latter form is, however, superior to the ordinary network chart form, first because it permits two of the readings to be made as intersections on the U and V scales as in the ordinary alignment diagram, and secondly because interpolation over a set of W-curves is done more easily and accurately through tangency relations than through location of point and curve.

Let the given equation be $E = I \cdot R$ as before. Let R and I occupy the straight line scales and E be the set of curves for a quasi-alignment diagram. Let R run from $R = 0$ to $R = 3$. Let I run from $I = 0$ to $I = 2$. Let the diagram fill a rectangle where $B = 2$, $H = 3$. Then $r = 1$, $i = 3/2$. We have also, differentiating $E = IR$ partially with respect to R,

$$0 = R\frac{\partial I}{\partial R} + I$$

$$\frac{\partial I}{\partial R} = -\frac{I}{R}.$$

* u and v are arbitrary constants permitting adjustment of the U and V ranges to the available stem length of the U and V scales respectively, that is, to the height H of the rectangle. B is the breadth of the rectangle, as in Fig. 8.

Hence

$$X_R = 0 \qquad Y_R = 1 \cdot R$$
$$X_I = 2 \qquad Y_I = 3/2\, I$$
$$X_E = \frac{2R}{\frac{3}{2}I + R} \qquad Y_E = \frac{3E}{\frac{3}{2}I + R}.$$

These equations give rise to the quasi-alignment diagram of Fig. 20. This figure could also have been found graphically by the method of Fig. 16. It is a dual to the type of chart in Fig. 9(c1) and is given here simply for illustrative purposes, since the complete rectification of 9(c1) as in 9(a1) and 9(c2) made it possible to create the superior alignment diagrams 9(a2) and 9(c3).

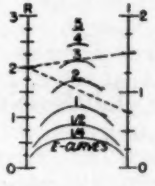

FIG. 20.

Our Need of Further Research

By DUGALD C. JACKSON
Massachusetts Institute of Technology

We all know that the engineering schools are deeply engaged in special instruction for war purposes in addition to usual instruction for civilian students, and no measures can appropriately be taken which would divert attention from the instruction which is provided for aid in the great war.

However, the war will end sometime, with victory on our side, and then rearrangement of the engineering school activities will be definitely facing each faculty. To wait until that moment before thought is given to the rearrangement will be very disadvantageous to the status of engineering education and its serviceability to the nation and its industries. Therefore, it is desirable for the administrative officers and faculties of the engineering schools to make assignments which will enable the study of the future needs to go forward now as well as hereafter, without interfering with war activities.

For this reason I set forth the following outline of some features which deserve attention and research for the purpose of maintaining the high standing of the educational service of the engineering schools. The points mentioned will be found referred to but not notably developed in my report on "Present Status and Trends of Engineering Education in the United States," which was prepared on behalf of the Committee on Engineering Schools of the Engineers' Council for Professional Development (E.C.P.D.) and which was published in 1939.

I

One of the first things to be brought into mind is the fact that a failure to recognize the proper use of research as a vitalizing influence in all levels of engineering education will after the war be more than ever a misfortune in engineering education. Research (mathematical, physical and economic) deserves to be recognized as a requisite factor in engineering education, and to be held in a high place when planning the paths of students from the sophomore undergraduate level to the most advanced graduate levels, because engineering of a high order is a research occupation since improvements are always crying for consideration. This view of the characteristics of research is one of the features that we should come to accept as a common objective in all engineering education, and the faculty formulation of plans for carrying out the objective in an effective manner is highly important.

The questions of appropriations for research should be open for careful examination, and the relationships which engineering experiment stations and research institutes belonging to educational institutions should have in engineering education need careful study. Unless these important questions are given wise consideration by the admin-

istrative officers and faculties of the engineering schools there is likely to grow up a tendency toward the laboratories for research becoming substantially closed or confidential enclaves within the educational institutions, with the result of barring the engineering students from the tremendous inspirational influences that come from themselves working in the research (the more fundamental, the better) and thereupon discussing the processes and results. Such exclusion also tends to divert the students' minds from an understanding of the importance of initiative and research as a part of definite engineering practice.

The war experiences of many industries will presumably have shown them the need of this fundamental research viewpoint being established amongst their competent young engineers before the latter are drawn from the educational sources, and these industries, therefore, may become more generous even than heretofore in contributing to research work in the laboratories of engineering schools, without requiring the laboratories to be held as confidential establishments.

The improvement of character, of resourcefulness, of judgment, of self-reliance, of efficiency, of understanding of men, and of engineering technique on the part of students is the comprehensive objective of engineering education, and the development of research mindedness in a very broad sense affects all the factors of this group.

In order to meet all the needs indicated by this objective, fuller examination is yet to be made into the intellectual interests, attainments and productivity of the teachers and into the quality of their teaching as individuals and collectively (accompanied by a better definition of the meaning of the term "quality of teaching"); as well as into the degree to which, and the methods by which, students are encouraged to sound and indepedent thought and work during their student careers. This investigation is fundamental enough and comprehensive enough to make it worthy of assignment to a committee of distinction comparable to the Committee on Engineering Schools of E.C.P.D., with a mandate to carry on the investigation over a sufficient period to bring forth conclusions and recommendations which would truly influence the whole of engineering education. The qualtities which are needed in engineering teachers are somewhat broadly outlined in pages 46 to 49 inclusive of the report on Present Status and Trends just referred to. This question of the "manpower" comprised in the faculties of the engineering schools becomes more important with each decade.

In association with this a reference may be made to the latter part of page 63 and the whole of page 64 of the aforesaid report, and emphasis may be put upon the fact that a good many American engineering schools do not respond to the test of important desiderata except in part, and a few miss them almost in whole. A careful examination of the situation is needed in order to outline the path that ought to be pursued in the effort to better the situation.

The extent of responsibility which, in engineering schools, ought to be laid upon the faculties for originating and approving educational policies and courses of study should be fully expressed by the chosen committee in order that administrative officers may recognize their duties as leaders in educational administration and refrain from narrowing faculty considerations

to details. Along with this there needs to be considered measures for promoting a fuller understanding of the objectives of engineering education by the administrative officers of many institutions where the engineering schools now are weak.

II

A very important factor in the situation is to be found in connection with the discussions of the tables and charts of the previously mentioned report on Present Status and Trends. As pointed out in the report, it would be of service to every engineering school, and to the engineering profession, if we could learn: (1) wherein and why weak institutions are weak; (2) whether those institutions that have thus far not succeeded in securing accrediting for any of their curricula ought to attempt to achieve an accredited status or whether it would be better for some of them on account of local conditions to relinquish the effort of professional education and turn their abilities toward collateral fields as Technical Institutes; (3) whether institutions that have only a minority of their curricula accredited should be encouraged to bring their curricula all to an accredited level, or whether some of their curricula that have not been accredited should be discontinued so that the institutions might more effectually concentrate their purposes and efforts within their financial strength; (4) whether the institutions that have a majority or all of their curricula accredited, or any of such institutions, may be improved in their attitudes and their influence, and the welfare of engineering thereby be enhanced. These problems are of significance to the whole engineering field. Their solution would enlighten every engineering school and be of service to the professional engineering societies and the American industries.

In connection with all this there needs to be a fuller investigation of the individual qualities of all of the engineering teachers, particularly respecting the creative qualities which are indicated by their writings and their investigations, and their influence upon students' minds (together with their interests in the latter); and in this connection thought should be given to the greater emphasis that ought to be placed upon the qualities of individual men when being selected for positions in the teaching ranks, with a diminished weight placed on the particular degrees that these men may hold. A higher degree is an appropriate indicator of the ambition of a young man, but it must not be overemphasized even for this purpose, and it must be recognized that as now conferred it may not be a sound indicator of the young man's appropriateness for membership in an instructing body.

The question of professional interest and ambition amongst the teachers employed in the engineering schools is notably touched by the proportion of memberships held in the appropriate societies, like the great national engineering societies and the S.P.E.E. Is there not something wrong when not two-thirds of the full professors teaching engineering subjects are members of S.P.E.E., as is shown by Table 10 of the report on "Present Status and Trends in Engineering Education in the United States" to be the situation a half-dozen years ago? This relationship, as well as the memberships in the national engineering societies, is discussed at some length in that report. Is it not important that the full professors should show a greater pro-

fessional interest in their teaching and thus secure an influence on the other members of the staff, leading the latter to the contribution of a greater professional interest? It may be that common sense would give an affirmative answer to this question; but, if that is so, investigation should be competent to bring out the reasons for the present inadequate situation. If the affirmative answer is not obvious, investigation should uncover the correct answer. Memberships in appropriate societies indicate creative-mindedness of professional character, and therefore the statistics of these memberships are worthy of some considerable thought.

A thoroughly fundamental subject for further investigation is a critical study directed toward determining what qualities of education do, in fact, lay the most sufficient educational foundation for the engineering activities of engineering school graduates. Until the answer to this is fairly well formulated, the true definitions of the objectives for engineering education and the qualities of engineering teachers must remain rather vague. President Doherty of S.P.E.E., President Wickenden of Case School, and others have written very persuasive comments on the qualities required for engineering education, but the situation is still open for adequate committee investigation. As pointed out in Present Status and Trends, the soundness of the central structure of engineering education as it has evolved has been so abundantly demonstrated that a further comprehensive study to develop more exact definitions in the directives and to formulate measures for avoiding weaknesses would be a major service to engineering and also to the nation in general.

These factors are within the realm of S.P.E.E. but also are appropriate for mutual treatment by S.P.E.E. and E.C.P.D. because of the importance of sound engineering education to the great engineering societies represented in E.C.P.D., and to the nation's industries, for the welfare of which the engineering societies play an important part. The coöperation which has now arisen out of joint efforts by S.P.E.E. through its Committee on Personal Development, of which Dean I. C. Crawford is chairman, and E.C.P.D. through its Committee on Professional Recognition, of which Professor C. F. Scott is chairman, points a way; and thereon (or some equivalent arrangement) might be laid the responsibility for examination into the qualities of engineering teachers.

It must be remembered that we have progressed in our present points of view and our present practices since the previous S.P.E.E. investigation of engineering education was made, which progress has been accomplished with the help of that inspiring report; and the new investigations should relate to the situation as it now is.

III

In the foregoing I have said nothing about the problems relating to the selection and guidance of students expecting to go into engineering, and certain features of the methods of teaching. These are very important matters, but the project which has now been entered upon with the mutual undertaking of the S.P.E.E. and the Carnegie Foundation for the Advancement of Teaching should bring light on these important questions without additional projects in this field.

Education of the Engineer

By N. W. DOUGHERTY

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The education of the engineer begins in the home and continues throughout his life. During the early stages of his education he forms habits of study and methods of approach which determine whether he will be educated or whether he will be an ignorant handbook technician who wishes he had studied certain subjects in college. To succeed in a profession the practitioner must always be searching for better methods of doing his daily tasks: if he ceases to search for new things, that day he settles down to the monotony of a skilled trade performing his work without imagination or inspiration. His college training is a preparation for a life of activity, on an ever increasing scale, and as a consequence it must be made a foundation for a life of intellectual growth.

What, then, is the place of the college in the education of the practitioners? It certainly is not an end within itself. Its courses do not contain all the education needed by a professional man. It is not an institution which, like a factory, finishes a uniform product in four, five, or seven years.

College education is a magnificent interlude between adolescence and young manhood; it is the prelude and the first degree of initiation leading to professional practice.

We have stated that college education is not an end within itself. Whenever its graduates "thank God that they are educated and do not have to study any more" it has failed in its major objective; its satisfied graduates have not learned enough to get to first base in the game of life. They will go through their professional careers wishing the college program had included needed information which they are too lazy to acquire as they need it. Reading books has become a chore and they are thankful that they do not have to read any more. To think of college as a place to acquire all the needed learning of a lifetime is to miss the point of the whole business.

Neither is a college program a series of credits with the registrar, though certain credits are kept and are spread upon the records. Too often students are concerned with the number of credits they have accumulated but can not remember the subjects they have studied. To some of them college is a place where they pass courses and when the total credits reach 120 semester hours or 180 quarter hours they are educated and will receive their degrees. In engineering, it is hard to possible to accumulate these credits without some plan because the faculty have fixed the program, but where the elective system prevails a student may choose very widely and spread his education very thin. The account with the registrar is incidental and does not

always show the education of the student.

College education is not a standard liberalizing experience which may be determined by comprehensive examinations. Two students may pass an examination and yet one be a great education success and the other may fall by the wayside in ignorance and self-sufficiency. It is more than acquiring a certain level of proficiency and a certain kind of educational technique. It is the foundation for a lifetime of study. Comprehensive examinations are probably as good as the account with the registrar, but they are not a college education. Education is not a level of mental gymnastics or a standardized stage in the educational process.

Does the concept that college education is an interesting, if not magnificent, interlude between adolescence and gainful work make any difference in what we should expect from it? If we think of college as not being an end within itself and not as a certain minimum attainment in intellectual gymnastics we may think of it as a part of a lifetime of study. It is probably the most profitable four-year period of an intellectual career; it is but a part of a continuing process. From this point of view we can see more clearly what should be accomplished during the training period.

College is a place where a student may develop his own educational aptitudes and there is no obligation on the part of the college to make its products uniform. If it does, Ruskin's indictment "A college is a place where diamonds are dimmed and pebbles are polished" will be truer than we like to believe. It should be a place where diamonds are polished and stones are put to a suitable place in the arch of life. Certainly the college is on the defensive if it fails to improve all the raw materials which enter its doors. If it is admitting materials it cannot improve, it should change its methods of admission.

A real university is a congenial place for young men and women to attain intellectual growth. Its laboratories, its libraries and its faculty are combined to give opportunity for mental activity. There is some drudgery and hack work but these are incidental and not the real tasks of the college. Mental inertia is greater than physical inertia; intellectual laziness is greater than physical laziness. To overcome these the colleges have established roll calls, drop quizzes, pages of assignment, and regular reports. These are the paraphernalia of mass education and not necessary parts of it.

If we think of education as a continuing process it will logically follow that the college courses must be the basis of a long life of study. Subject matter will not be chosen because opportunity for such study may never come again but rather it will be chosen because it must be a part of the life program. Some subjects are difficult to master without basic preliminary knowledge and in some cases without peculiar techniques. In college, then, the student must get this basic training and he must acquire the techniques of gaining knowledge. There are subjects on which a lifetime of study in engineering must be built: mathematics, physics, chemistry, mechanics, hydraulics, thermodynamics, economics, English, etc., and there must be enough technology to get the method, attitude, and approach to engineering problems. If a student acquires the study habit and the scientific method he will be able to get the needed information whether he knows where to

get it or not. It is a part of his education to learn how to find things which are hidden from the uninitiated.

This approach to education magnifies great teachers. They embody the educational desire, they use the educational method, and they inspire to educational effort. Much education is by contact and contagion and not by formal lecture and assignment. A good teacher will present his subject matter well, but he will teach more than is in the textbook or the report; he will influence their very living. President Garfield described a college as a log with Mark Hopkins on one end and a student on the other. Mark Hopkins was one of the great teachers of his day; yes, one of the great teachers who have taught in American colleges. It is folly to think that any teacher can do a good job if he follows the assignments and meets his class regularly. He must know his subject, he must meet his class regularly, and most of all he must be able to inspire his students in their search for knowledge. They must remember how he talks, how he walks, how he thinks and they, if they are really taught by him, will mimic his methods even to his walking and talking.

For the student, his college days are his trying days, his testing days; his days of growth where he can recognize mental development and maturity along with his physical change from a boy to a man. If a student fails to mature and fails to become imbued with a love of knowledge he will go away from college as an overgrown adolescent who may never approach mental manhood. Here is the time for the student to test his own abilities, to learn his capacity for work and accomplishment, and to know what educational tasks he can undertake successfully. Mental effort causes the mental qualities to grow like physical effort causes the muscles to grow. Mental laziness has the same effect on the mental abilities as physical laziness has on the muscles of the body—they become fat and flabby and unable to respond to stimuli.

We are urged to go back to the good old days in education, we are urged to go back to the Constitution, back to the religion of our fathers, and back to Jeffersonian democracy. Usually the trek backward is to avoid some difficulty of today. A move into new methods and new ways may give a better solution.

There is no going back after the day is done. And could we go back we would be disappointed. Don't try to live your honeymoon over; it will never be the same again. Cherish the past in memory and get inspiration from it but continue to live in the present; learn the "wisdom of the ages" but don't forget that the sum total of knowledge has been greatly increased since engineering came into the schools.

The successful engineer of the last century was a good student; and this more than his college training made him a good engineer. A lifetime of study is what makes a good engineer today; the same law was in force during the last century. What we study is important but how we study, and the amount of study are equally important. There is no reason why any kind of professional knowledge should be denied to any intelligent practitioner if he is willing to put a little time on the study of the subject. Who were the teachers of Newton, Shakespeare, Edison, and Steinmetz? They were their own instructors; no living teachers had reached their standards of excellence. Why must an engineer

always have a tutor at his elbow in order that he may learn the things he needs to know? Should college professors always be glorified chefs who prepare soft morsels for slothful intellectual appetites?

In the "Report of the Committee on Aims and Scope of Engineering Curricula" * is outlined the work which should be done in a four-year program, recognizing that there is need for further study for those who enter the profession.

Provision for postgraduate education is necessary, furthermore, if adequate time is to be allowed in the undergraduate period for thorough grounding in the basic sciences, for laying the foundations of a social philosophy, for developing powers of effective expression, and for cultivating reflective and critical habits of thought. If the undergraduate period is concentrated chiefly on these objectives, and if, at the same time, an adequate introduction is given to engineering methods of applying science to actual problems, the value of the four-year program, we believe, will be enhanced.

To fulfill this definition of a four-year program the committee outlines the work which should be done. This statement is the best made to date.

One of the most important phases of engineering education is the engineering method. We would expand method to include the engineering attitude, spirit, and approach. The committee suggests that we should teach young engineers how to think straight.

We must not confuse ability to think with ability to criticize or ability to find fault. Ability to quote authority is often impressive, but not necessarily an ability to think. If a current problem parallels some previous problem where authority has spoken, it is foolish not to heed the words of wisdom, but new situations are constantly arising in engineering which require knowledge not possessed by an ancient authority.

To think straight, the engineering student must learn to be critical, learn to weigh evidence and not forget his previous experiences. A combination of these qualities aids in thinking.

The engineer who has failed to read great literature has neglected a mine of golden opportunity. He should have enough instruction in college to give him a discerning appetite for literature. Instead of "pin-feathering" the masters, he should learn to read them understandingly. He should not read literature as a social duty, but as pleasant and profitable communion with the great minds of the past.

Four years at college are certainly different from any other four years of life. Eight, ten, and even more hours a day are available for study. Never again will such opportunity knock at the door. It may be that a student will only use two or three of these hours profitably yet they are there for his use, if he will only wake up before the days are gone. During his forty years of productive career he will have one to three hours available for daily study. These will be enough for him to master anything he needs to know provided he has learned how to apply himself to the task.

By considering education as a continuing process we are able to explain the great success of the engineer who graduated before modern theory was developed. He did not learn much theory in college and as a consequence he developed it as his work required. This also explains why the graduate from a school which offers meager training can compete favorably with the

* JOURNAL OF ENGINEERING EDUCATION, Vol. XXX, No. 7, March 1940.

graduate from the best equipped school in the land.

Considering a college education as an interlude between adolescence and maturity will give us more freedom in selecting a program of study. If we close the books at the end of the college program, we must acquire the needed useful knowledge or it will never come our way again. By considering college as a development period which will continue for many years, we can then emphasize methods of learning, not information *per se*.

What then shall we say about education for the engineer?

A few things are self-evident.* The student must certainly learn the language of the profession, he must learn its basic sciences, he should learn the laboratory method, the research approach, and he should learn enough technology to become acquainted with the method attitude, and spirit of the profession. In addition, he should learn its code of ethics and the peculiar techniques of its practitioneers.

Certainly the engineer must be a citizen of the community, state, and nation in which he lives. He must learn, either in college or elsewhere, enough history, physchology and civics to be a good citizen. Introduction to these fields, during his college course, will help him read with discrimination the vast literature in economics, government, and human relations. A few basic courses, under wise teachers, may may start him on the way to good and active citizenship rather than leave him as an easy mark for crack-pot reformers and milk bottle philosophers.

Let our teachers of engineering strive to produce one, if not many, engineers in each class who will enter a lifetime of study and scholarly production. Note this old workman who stated that he had sat at the feet of Gamaliel: ". . . and the time of my departure is at hand. . . . I have fought a good fight, I have finished the course, I have kept the faith. . . .

"The cloke that I left at Troas with Carpus, when thou comest bring with thee, and the books, but especially the parchments."

Here is a man who "turned the World upside down," who is lodged in a Roman Prison and in his last days he needs the books and the parchments as badly as he needs the cloke.

Engineers, to make their place in the profession, must learn to use the books and the parchments of their calling, and more, they must learn to continue communion with the best minds of the ages.

* *Proceedings*, American Road Builders Association, 1938, p. 722.

First Evaluations of an Accelerated Program in a College of Engineering

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The past year has seen sundry efforts at acceleration in engineering education. Early attempts to appraise results seem highly desirable. Ways might be suggested for the improvement of special programs during the war period. The findings might have bearings on problems of educational re-adjustment immediately following the war. They might indicate means by which, after the emergency, engineering education might be made better. The present paper reports certain data regarding the accelerated program in engineering at the Ohio State University, with reference to possible values in the respects mentioned above. A broad approach was attempted, with a view to comparing accelerated with non-accelerated programs, and finding how acceleration affected not only academic progress but the total existence of these students while in college.*

Gross Amount of Acceleration

The first question naturally is as to the amount of time gained and number of students who did accelerate. The following table shows, for the pre-acceleration school year 1941–42 (graduates in the summer and autumn quarters of 1941 and winter and spring of 1942) and for graduates in the school year 1942–43, the number of years and months from entrance to graduation, for those students who took all their college work at the Ohio State University. The table is in per cents of each class taking the indicated length of time.

TABLE I

Years and Months from Entrance to Graduation

	Under 3–6	3–6	3–9	4–0	4–3	4–6	4–9	5–0	Over 5–0	Total	Median
1941–2			49	4	6	5	20	2	14	187	4–1
1942–3	1	37	19	9	4	16	4	3	7	217	3–11

In the last school year, the median time from entrance to graduation was two months shorter than the year before. In 1941–42 more than half (51 per cent) took more than the "regular" time (3–9 years or graduation the fourth June for those who entered in the autumn quarter and equivalent time for the few entering at other quarters). And the question might be raised as to whether a more

*The study is one of a series regarding educational acceleration being made at the Ohio State University by the Bureau of Educational Research, under the general direction of Dr. Pressey.

rapid output of engineers might be better obtained by helping such lagging students finish more promptly than by a four-quarter program for all. In 1942–43 only 38 per cent finished in the accelerated regular time for graduation—the fourth March after entrance. None in 1941–42 and only 1 per cent in 1942–43 finished under the "regular" time. But 16 per cent in the first class and ten per cent in the second took five calendar years or more (of course, not necessarily all of that time in school). In short, in the usual college set-up it is relatively easy to lag behind the crowd, but rare to get ahead of it, though there is every reason to assume that a considerable number of the most able students could do so.

The next table (which includes transfer students) shows the effects of acceleration on age of graduation. A "regular" student entered elementary school either in his sixth year or shortly before his sixth birthday, and then spent twelve years in elementary and secondary school, entered the University at 17 or 18,* and graduated four years later in his twenty-first or twenty-second year. Such is the educational lock-step. Acceleration did not increase the proportion of distinctly young graduates (under 21). But median age is lower by four-tenths of a year and number graduating after the twenty-fourth year decreased 7 per cent—very likely some of the older men made special efforts to finish because of the war.

TABLE II

AGE AT GRADUATION

	Under 21	21	22	23	24	Over 24	Total	Median
1941–2	3	21	28	19	12	17	233	22.9
1942–3	3	29	33	17	8	10	273	22.5

The table next following presents somewhat unusual comparative data, going at the problem in a somewhat unusual way. It shows the per cent of students entering the college of engineering as freshmen who finally graduated either in engineering or in some other college of the University. The data are for the class entering 20 years ago (the autumn quarter of 1923), a class graduating before the war situation could affect it much (entering in 1936) and the immediately pre-war class entering in 1938 as well as the war class entering in 1939. The general situation here shown is practically universal in higher education. Apparently it has improved a little since 1923. But even the accelerated class which entered in 1939 shows only one fifth with the degree the fourth year thereafter. Of the '36 and '38 entrants, only 31 per cent and 32 per cent had obtained the engineering degree five years after. Surely such a high academic mortality needs attention—and might be reduced.

* As a matter of fact, the per cent at each age at entrance, of graduates in these two years who obtained all their work in this college, was as follows:

	16	17	18	19	20	Over 20	Total	Median
1941–2	4	27	41	12	9	7	187	18.5
1942–3	1	27	48	15	5	4	217	18.5

The two groups were practically identical as to age at entrance. Entrants over 19 were rare. Immediately after the war there will presumably be many more older entrants, coming from the Services or industry. A heterogeneous group, including such men with boys straight from high school, will present many problems.

TABLE III

PER CENT OF FOUR ENTERING CLASSES IN THE COLLEGE OF ENGINEERING WHO GRADUATED

Year of Entrance	1923*	1936	1938	1939
Number of entering freshman	350	572	507	585
Per cent graduating in 4 years:				
In engineering	13	18	19	20
In all other colleges	2	2	4	1
Total per cent graduating in 4 years	15	20	23	21
Per cent graduating between 4 and 5 years				
In engineering		13	13	
In other colleges		5	2	
Total per cent graduated, end of 5 years				
In engineering		31	32	
In other colleges		7	6	
Total per cent graduated, end of 5 years		38†	38	

*Edgerton, H. A. and Toops, Herbert A., Academic Progress: "A Four-Year Follow-Up Study of the Freshmen Entering the University in 1923," The Ohio State University Press, Columbus, Ohio, 1929, 150 p.

†A follow-through to June 1943 showed 4 per cent more receiving a degree up through that time. The total of 42 per cent who had received some degree by the end of 7 years may be in part a result of the war; more may have finished than usual, because of the value of a degree in the war period.

In this connection the results of a little rough figuring seem of interest. The first table showed median time from entrance to graduation to be two months shorter in 1942–3 than in 1941–2. If 217 students saved an average of two months, the total gain was 434 months or about 36 years of time. The previous year, without acceleration, 67 of the graduating class took five or more academic years (4–9 calendar years) from entrance to graduation. If 36 of these students, or slightly more than half, might have been so helped that they could have finished in the regular time, the same total time might have been saved. Or suppose only a tenth of the over 370 1936 entrants who dropped out of the engineering curriculum (or at least had not, seven years after, obtained an engineering degree) had been helped in some way so that they remained until graduation; such an increase of 37 engineers would surely have been a greater gain than the two months gain for those who did complete their training.

Some institutions have been admitting superior high school students in advance of high school graduation. After the war many students will return to begin college careers at older than usual age. And the question is raised as to whether students exceptionally young or old are more or less likely than students of average age to graduate. The next figures offer a bit of evidence bearing on this matter. They combine data for students entering in the autumns of 1936 and 1938 and show the number entering

at each age and per cent who had graduated in either engineering or some other college of the University by the fifth year after entrance.

Age at Entrance	16	17	18	19	20	21	Over 21
Number of students	14	228	454	179	83	47	62
Per cent graduating	71	45	40	30	40	38	18

The best academic risks—most likely to graduate—are those who enter young. Students over 21 are a bad risk. The post-war older student may be a very different individual than the older student in pre-war days. But after his war experiences he may be even less willing to stay through a difficult four year program, with consequent delay in beginning of career and also probably in marriage and economic independence.

Effects of Acceleration on Quality of Academic Work

The most obvious question as regards quality of academic work, is as to comparative grades of students graduating in accelerated and non-accelerated classes. The median P.H.R.* of the non-accelerated class of 1941–42 was 2.53 and 21 per cent had an average grade of B or better while 1942–43 figures are 2.55 and 20 per cent, or practically the same. However, possible effects of acceleration upon grades would show more clearly if grades of all students, not simply those who met graduation requirements, were considered, and comparison was made between students who had and had not attended summers, or taken extra courses, in the same school year. Moreover, 1942–43 instructors might have graded somewhat more leniently than before, to make allowances for the distractions of the war and the burdens of acceleration upon the students. The excitement of the war might either interfere with school work or motivate it more strongly. But if comparisons were made therefore for the school year 1942–43 between students who were and were not accelerated in some way, such influences might be supposed to affect both groups, and therefore not be an important factor in any differences between them. The next table summarizes such comparisons. It first compares students

* The Point-hour-ratio is the number of points divided by the number of hours, a grade of A counting 4 points, B 3, C 2, D 1, and E 0.

TABLE IV

Number, Median Age in Years and Months (as of March, 1943), Median Percentile on Test of General Ability, and Scholarship (Cumulative P.H.R.) of Students who Attended Summers (and those were Registered all Four Quarters) as Compared with Students in Attendance only Three Quarters, and of Students Carrying Heavy as Compared with Light Academic Loads.

	Number	Age	Ability	P.H.R.
Sophomores:				
No summer	59	19–8	78	2.50
One summer	120	19–9	83	2.42
Juniors:				
No summer	17	20–7	73	2.43
One summer	103	20–11	78	2.44
Two summers	51	20–10	82	2.31
Seniors:				
No summer	3	24–5	75	2.50
One summer	57	22–5	87	2.65
Two summers	46	22–1	82	2.60
Three summers	13	21–4	88	2.75
Sophomores:				
Load under 19 hours	115	19–9	80	2.57
Load 19 hours or more	64	19–8	84	2.69
Juniors:				
Load under 19 hours	104	20–10	80	2.32
Load 19 hours or more	67	20–10	78	2.51
Seniors:				
Load under 19 hours	71	22–3	82	2.58
Load 19 hours or more	48	22–0	89	2.73

who, at the end of the winter quarter 1943, have attended one, two or three summers with students who had not done so. As will be seen from the first column, many students did not accelerate by attending four quarters, though the opportunity was available.* Those who did, averaged slightly higher on the Ohio College Association test of ability given at entrance to the University. Taking all classes together, there is no consistent relationship to age or scholarship, though the few seniors who had been registered three summers were youngest, ablest and had the best academic record. What little other evidence is available appears to be in accord with this conclusion that, for a while at least, students can attend school summers as well as during the regular school year without evident slump in quality of school work.†

The lower part of the table compares students taking a course load less than 19 hours with those averaging 19 hours or more. In age the two groups are practically the same; those with heavier load average slightly higher in ability; and in each class those with heavier load show a slightly better academic record. Since presumably students who are not burdened with jobs and who are highly motivated take heavier loads, the outcome is not surprising. But at least it indicates that many students can successfully take schedules heavier than average.‡

One further comparison was made. The class records of the department of Mechanics were available, for the pre-war school year 1940–41, the transition year 41–42, and the war year 42–43. Table V summarizes the findings. The Department has high standards and grades carefully; median point-hour-ratio throughout is low, but lower in '40–41 than in '42–43. Absenteeism is up only slightly in the war year.

In short, the evidence is throughout that school work shows little effect of acceleration. Standards of grading may have gone down, or grades be too rough a measure to show the effects. But the above evidence is that students are taking the accelerated program in stride.

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* This situation appears typical of schools of engineering. Thus registration figures from 52 institutions for the summer of 1942 showed that "The summer terms are accelerating the training of only half of our undergraduates." For data on this question see "Report of the Committee on Acceleration of the Regular Engineering Program," J. ENGR. EDUC., 32: 155–57, Oct. 1942.

† See for instance Beardsley, S. W., Schweers, J. M., and Fleisig, R., "Evidence Concerning Efficiency of Accelerating Engineering Education," J. ENGR. EDUC., 32: 157–163, 1942.

‡ For more exact comparisons, the method of paired cases was used. Thus a sophomore who had attended during the summer (and thus by March 1943 had been in school six quarters straight), whose home was in Columbus, who was 20 years old, at the 88th percentile in ability, and majoring in electrical engineering, was compared with another sophomore who had also taken six quarters straight, was living at home, was of the same age within five months, of the same percentile rank within 15 points, and also majoring in electrical engineering. For the sophomore and junior classes 91 such pairs were found, for comparing those who had been in no summer, one summer, or two summers. Median point-hour-ratio for the first group was 2.40 and for the one summer and two summer cases 2.35. Forty-six pairs were found for heavy versus light loads; the median point-hour-ratio for heavy load was 2.60 and light load 2.35. In short, the results confirm the more rough comparisons given in Tables IV and V above. . . . Acknowledgment may well here be made to the competent work of Miss Mildred Van Nest in handling the data of this total investigation.

TABLE V

GRADES, ATTENDANCE, AND AVERAGE CLASS SIZE IN SIX LARGE COURSES IN MECHANICS IN THE SCHOOL YEARS 1940–41, 1941–42, 1942–43

School Year	Number of		Class Size	Median P.H.R.	Per Cent Absenteeism*
	Classes	Students			
1940–41	45	1,048	23	1.60	6.0
1941–42	44	1,138	26	1.75	7.0
1942–43	37	950	26	1.75	7.0

* Per cent of absenteeism $\frac{a}{bc}$ 100 (a = Total absences; b = Number of students registered; c = Number of scheduled lecture meetings).

EFFECTS OF ACCELERATION ON HEALTH AND RECREATION

The preceding section has indicated that students could, at least for a short time, do intensive college work without lowering of academic standards. However, if intensive work were done only at a cost of poor health, and lack of any recreation, or desirable social life, then the cost might be too high except perhaps as a war emergency. To get evidence here, two steps were taken. An extensive inquiry form was filled out by a total of 165 junior and senior students. And an able senior made it his business to talk with other students as widely as possible and sound out informally their attitude toward some of these questions. The next table shows per cents of the 165 upperclassmen who checked certain items which seemed of special significance, on the inquiry form.

The table shows that 61 per cent of these engineers felt that their social life was limited and 19 per cent were members of no professional, social, athletic, or other group; 13 per cent considered themselves fatigued most of the time; 36 per cent thought that they were doing more school work than was desirable, and 25 per cent considered their education hurried; 70 per cent thought that accelerated programs should be dropped after the war. Moreover, 59 per cent felt their summers to be most worthwhile when they worked—presumably in jobs of some professional relevance. Significant of the burden some students were carrying is the fact that 25 per cent said they were working while in school over 15 hours a week to earn money, while 51 per cent declared they had no time for exercise.

Similar results might have been found if the inquiry had been made before the war; the difficulty of the engineering curricula, rather than the stress of acceleration, may be the important factor. But anyhow, it appears that many students are now

TABLE VI

PER CENTS OF 165 JUNIOR AND SENIOR ENGINEERS CHECKING CERTAIN ITEMS ON AN EXTENSIVE QUESTIONNAIRE REGARDING ACCELERATION

Social life:	
Limited	61
Member of no group	19
Health:	
Under par or poor	5
Fatigued most of time	13
Amount of school work:	
More than desirable	36
Could take more	3
Education too hurried	25
Acceleration should be dropped after war	70
Summers most worthwhile:	
Working	59
Going to school	42
Travelling	18
Resting	11
Spent *no* time during past week in:	
Leisure reading	29
Exercise or sports	51
Dates, social affairs	43
Spent over *15* hours working	25
No work experience of any kind	3

working too hard, and lack desirable recreation and balanced normal life. And these conclusions were verified by the observations and inquiries of the student investigator. Not recognized by his fellows as so serving, he drew them into casual conversation about their work and their leisure, watched them in rooming house and college hang-out and on evenings off. Superficially there was a "what's the use" attitude on the part of some; good-bye affairs for an associate called into the service might demoralize existence for several days; financial need plus the many opportunities for good money in war industry led some into an almost impossible total burden of study plus job. Tempers were often short. But youth carried on.*

And though aside from issues dealt with in this investigation, it may well be stressed here that the burden upon the faculty was indeed great, with reduced staff and increased load of teaching, administrative duties, and war-needed research. That the students maintained good academic standards in the accelerated program would indicate that instruction had not deteriorated. But no one acquainted with an engineering faculty could doubt that the cost in health and normal living had been heavy.

Acceleration and Post-War Engineering Education

To many faculty members, acceleration is a war burden, to be got rid of as soon as possible. But after the war men will return to college who have been in the services or war industry and who, being several years older than the average entering student of pre-war days and much more mature and experienced, will very likely desire to complete their education in a shorter time than formerly. No less a person than President Wickenden of Case has declared that "Programs of the transition period must inevitably be of an intensive, possibly even hurried, character. . . . We shall be dealing with young people who, while educationally belated and out of touch with a world in which they have never had an economic place or a social stake, are nonetheless physically and psychologically mature beyond their years."† Moreover, increases in efficiency if not a shortening of time might surely be hoped for, in education as well as industry, as a result of improvements stimulated by the war. What constructive suggestions, for post-war engineering education, may be made on the basis of the war-time experience with acceleration? Four suggestions are offered.

1. As pointed out in the first section of this paper, in the past less than a third of the students who began an engineering program obtained an engineering degree. And over a third of these took more than the "regular" four years.‡ The first step toward

*Mr. Arthur Kornichuk was here and throughout the investigation of very great aid in helping gather data, and interpret it from the student point of view.

† Wickenden, W. E., "Adjustments that should be Made in the Engineering Curricula for the War and Post-War Periods" An address delivered at the general session, The Association of Land-Grant Colleges and Universities, Chicago, October 29, 1942), *Virginia Polytechnic Institute Bulletin* 36, No. 1, November, 1942.

‡ Elimination and retardation are by no means to be blamed simply on poor student ability. Thus 55 per cent of the students entering in 1936 who scored in the upper fifth on the entrance test of general ability failed to obtain a degree in five years, most having dropped out of school. A valuable discussion of the importance and complexity of these problems will be found in "Report of the

increasing the efficiency of engineering education might be to reduce such educational mortality and retardation. Thus the previous section showed that a quarter of the students in residence during the past year had been spending 15 hours or more a week earning money. A considerable amount of elimination and retardation is probably due to financial difficulties. Funds for service men for the completion of their education should here greatly help. Also, some students have difficulty in engineering because of inadequacy of preparation, especially in mathematics and also sometimes in English and in study methods. Special classes to help these students remedy such deficiencies have been found of value.* By such financial and educational aids, and better guidance, more entering students graduate and with fewer delays.

2. After the war, many men will return to schools of engineering who have had special training for war service or industry, or special experience, which will give them more knowledge of certain types of engineering problems than pre-war entering students. Before the war a few able students from good high schools came to college with preparation in English, mathematics, or chemistry so excellent that they passed, by examination, the required freshman courses in these subjects before taking them. The students consulted in this investigation often mentioned that if more reasonable standards were set in such examinations, many more students might thus get a head start into their engineering training.

It is of great importance that after the war there should be means by which students entering an engineering curriculum with advance training or experience will be given credit therefor. Certain examinations now being prepared for the army may well here be of value.† It may well be that credit by examination should become as well recognized as credit by course-taking.

3. Under stress of the war, industry has not simply worked longer hours; even more there has been an effort to find more efficient methods by which time and labor might be saved. In strange contrast, universities and technical schools (which have contributed so largely to improved methods in industry) have accelerated "the hard way," by heavier course loads and elimination of vacations rather than by seeking more efficient means of doing their own work. A systematic effort to pool new ideas as regards both curricula and instructional methods and materials would seem highly desirable. From the total of educational innovations not only in the colleges‡ but also in army and industrial training programs, it should be possible to find methods by which in the aggregate substantial educational gains could be achieved.

Committee on Student Conservation," J. ENGR. EDUC., 33: 82–91, 1942.

* See for instance Robinson, F. P. "Study Skills of Soldiers in A.S.T.P.," *School and Society*, 58: 398–99, 1943.

† See, for instance, Tyler, Ralph W. "Appraisal of Military Training and Experience," *Journal of the American Association of Collegiate Registrars*, 18: 345–52, 1943.

‡ See for instance, P. F. Nemenyi and R. L. Lewis, "Plans for Special Acceleration of the Study for Senior Engineering Students of Superior Ability," THE JOURNAL OF ENGINEERING EDUCATION, 33: 850–865, June, 1942. Some of the special films and other instructional devices and the intensive streamlined courses developed in the army surely contain much of continuing value, even if streamlining there may have gone too far and work done under a pressure not healthy in peace-time.

4. This investigation has shown that some students can take more than average academic load, or go to school throughout the year. But it has also shown that some of these students (and some others taking only an average load) are suffering as regards recreation, social life, and health. It has pointed out that, after the war, students will come to engineering colleges with a great variety of backgrounds as regards special training and experience; and it may be added that these men will also present many problems of health and of social and emotional adjustment. Adequate guidance programs seem a necessity, if the program of each student is, then, to be planned with any reasonable adjustment to his background, capacities and needs.

Summary

1. A study of accelerated educational programs at the Ohio State University showed a saving of two months from entrance to graduation, for graduates in the school year 1942–43 over the graduates of the year previous. However, only 20 per cent of the entering class of 1939 received the engineering degree within four years—a gain of only one per cent over the entering class of 1938. Two-thirds of the average entering groups never complete the engineering program. It is suggested that such aid to students as would permit more of those who enter to graduate, and more of those who take more than four years to graduate in the regular time, would accomplish more than is accomplished by the elimination of vacations, and the extra work, of the usual accelerated program.

2. A variety of evidence all agreed in indicating that accelerated students did as well academically as the non-accelerated. Those attending four quarters did approximately as well as those in only three, and those taking heavier than average academic loads somewhat better than those taking lighter loads.

3. Inquiry by means of both questionnaire and interview indicated that under the accelerated program (though not necessarily as a result of it) many students were fatigued, spent much time earning money in addition to their school work, and lacked exercise, recreation, and a desirable social life.

4. Certain types of accelerated program will be needed to meet the post-war problems. The great danger in all fields of professional education is an attempt after the war to return to "normalcy" rather than to utilize war-time experience in efforts at solution of these problems. Suggestions are offered, in the light of the findings of the study, regarding post-war readjustments in engineering education.

A Revision of the Aeronautical Engineering Curriculum in the Light of Modern Aircraft Engineering Requirements*

By C. T. REID

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PART I

What are the modern requirements?

The day of vague generalities in the study of aeronautical science is past. We no longer speak of "The Study of Aeronautics," or "The Study of Aviation." Engineering courses, giving a sampling of every aeronautical subject from meteorology to stress analysis, with airport layout and management thrown in, are passe.

Our topic uses the phrase "Modern Aircraft Engineering." This is hopeful, but still requires explanation. We will exclude lighter-than-air craft from the present consideration. This narrows our field down to flying machines that are heavier-than-air, and for the current discussion we may take this to mean airplanes.

What then of the airplane engineering requirements? Well, it may quickly be conceded that further subdivisions would be needed to idealize the specialization of training to produce experts in the design of engines, or propellers, or structures, or other particular parts of an airplane. However, this seems to be carrying specialization too far. A top-ranking man in any of these fields is best produced by thorough basic training in mechanical engineering, topped off with post-graduate study in the specialty.

Perhaps in these days of accelerated training, we should seek a better suggestion than that all purely aeronautical subjects wait for graduate study. Also, it is well to bear in mind that standard four-year courses in mechanical engineering ordinarily occupy some time with studies of little practical application in aircraft engineering. They occupy such time because a general mechanical engineering course tries, very properly, to sample many fields of mechanical engineering. Considerable headway has been made in adjusting this condition for the benefit of the airplane industry by offering senior year options in a variety of subjects. The student who, by the end of his junior year, feels inclined to work on airplanes, may brush aside courses in steam and gas, or refrigeration, or Diesel engines, and take something introductory to airplane design. Many such courses in mechanical engineering, with "senior options in aeronautics," as they are called, are nowadays doing a fine job of training. Just how successful they are in fitting the new young engineer for his work depends to a great extent upon the exact nature

* Presented at the 50th Anniversary Meeting (Aeronautical), S.P.E.E. Chicago, Illinois, June 19, 1943.

of the work and how well its demands were understood and met in college.

We are led inevitably into a study of what the employer wants and expects of a new young engineer. Of course, this depends upon whether the employer is a military service, an airline operator, a manufacturer, or what? And if a manufacturer, it makes a difference whether he builds an airplane or just an engine, propeller, or some other independent special part of an airplane.

To move along into a more objective discussion, let us suppose that the employer is a typical airplane manufacturer. He buys his propellers from a factory which makes nothing but propellers. He obtains his engines from another factory that makes only engines. Do not think for a minute that he does not have knotty problems in power plant design to be solved! An engine comes from its maker without any fuel tanks, fuel valves or piping. There are no tanks or piping for the oil system, either. The engine control mechanism is yet to be created. So is most of the electrical system. Carburetor air scoops, with ice prevention provisions, exhaust manifolds, cowling with flaps and adjustment gear, and the major structure of the engine mount, are all left to be designed to suit the particular application.

So much for power plant engineering. What are some of the other jobs? Well, a couple of others, also using training in machine design, strength of materials, fluid flow, heat transfer, and shop manufacturing considerations, involve creation of the hydraulic system, and the air conditioning system. The hydraulic system consists of very superior and scientific plumbing, upon which satisfactory manipulation of many of the flight controls depends. The air conditioning system covers all the wide field from simple cockpit heating to elaborate pressure cabin provisions. Precision machined parts, dimensioned for economical manufacture yet reliable interchangeability in the field, are the principal components. A good appreciation of what can, and what cannot, reasonably be made in the machine shop, the forge, the foundry, and the sheet metal shop, is essential.

The same basic characteristics feature the engineer's creation of the mechanical controls, gun and bomb mechanisms, or useful load provisions of whatever kind. In all branches, a good practical knowledge of templates, jigs, tool fixtures, and dies, is required. Laying out on the drafting board the design details to produce strong lightweight structures of stiffened thin metal sheet does most all that is left of the job of engineering on the airplane.

Yes, it is true that we have not mentioned aerodynamics, or stress analysis, thus far, and yet we have covered most all of the work that our four-year engineering graduate finds a chance to do. No, the scarcity of opportunities for him on aerodynamics and stress analysis is not so much due to his lack of highly specialized post-graduate training as to another factor. *There just is not very much of those things to do!* Percentagewise, the men doing aerodynamics, or stress work, in an airplane factory's Engineering Department, are only a drop in the bucket. More than 80 per cent of the engineering is done right on the drafting boards. Most of this is mental effort. All of it is highly scientific. On the drafting board is where the airplane is conceived and born. Drawings made to show it are the manifestation.

Creating a modern airplane is a prod-

uct designer's job. A large share of it is so wrapped up in production manufacturing technique that one almost loses sight of aeronautics, periodically. Most of the myriad problems differ from those in the design of a submarine, a harvesting machine, or a railway streamliner, only in the scrupulous care given to strength-weight ratio in airplane work.

Of course, we want more aerodynamicists and stress analysts in the airplane factories! They are vital. It would be tragic if the colleges stopped turning them out. We don't want any reduction in the training of aerodynamicists and stress analysts. Eight per cent, or more, of the students, may well prepare for specialized duties on stress analysis or aerodynamics, because just about 8 per cent of the placement opportunities demand such specialization. But *above all else the changes needed in the curricula training our engineers are those changes which will send us men to work as designers.*

Why should the schools be slow to grasp this point? Why do professors openly discourage applicants from accepting a start on the drafting board?

Go to anybody's airplane factory and meet the Chief Engineer. Ask him, not how he "got his start," but what jobs he worked at before he became Chief Engineer. The chances are better than 10 to 1 that he has been a designer most of the time. We choose our leaders of specialty groups from among the ranks of designers. Our project engineers, in charge of work divisions by models, are the successful designers. The steps on the main staircase toward the Chief Engineer's office are draftsmen, designer, group leader, project engineer. This staircase leads on beyond Chief Engineer, too. If you will look up the biography of your favorite airplane company president, more likely than not you will discover that he came right up from the ranks of the engineering designers.

It would be a very good plan indeed, if even those students who choose to specialize in stress analysis or aerodynamics were required to first complete the regular course of training for product designers.

Part II

How can education and training satisfy the requirements

There is so much need of training emphasis upon *utility value in industry* that we must declare at the outset that industry has to assume a great share of the burden. Experience with ESMWT courses has shown us the tremendously increased value of studies laid out by industry and taught by college faculty members with recently renewed industrial experience. Industry must join with the colleges in assuming the responsibility for building the right curriculum. In many of the subjects, industry must go still farther and outline the detail content of the course.

There is only one place to find out what can and what cannot be done in manufacturing. That is in the shop. Since this knowledge needs to be developed along with, and as a means to, the unfolding of basic scientific training, the college people concerned absolutely require frequent and convenient access to manufacturing shops.

Coöperative courses come to mind. It is a fine thing for a college student to alternate between time in college and in industry. *A still better thing would be for every one of his instructors of engineering subjects to do that very*

thing themselves! Industry must face squarely the fact that no one can effectively teach what he doesn't intimately know. Since what industry needs taught is *how metal products are designed for production,* industry must provide the opportunities for professional educators to learn the factory and design room processes, and keep up to date by refreshing and renewing that knowledge repeatedly on a never ending coöperative schedule.

We must make available our reference and procedure manuals and sample problems from our new experiences. Dean Hammond has pointed out how the pattern of engineering education has been effectively determined by the texts used. Very few specialization text books and still fewer texts of fundamentals are able to give enough practical examples to clinch the learning process the way it can be clinched when emphasis is placed upon application to use. To those who fear that this would cause training to be too specialized, we remind that this treatise is offered "In the Light of Modern Aircraft Engineering Requirements." Inevitably comes the bewildered cry: "But how do we know the student will go into aircraft?" Our answer is: "Let him be employed in aircraft work for a while and find out." Let him change from full time study to full time work in the industries for several whole quarters, spaced throughout his college career. The people who follow this procedure always get the most out of college.

The engineering training that would now help the airplane manufacturing industry most would be a mechanical engineering course strongly flavored throughout with design for production.

A sample course outline is appended to this paper. As the outline is presently arranged, it shows twelve quarters of work instead of the usual sixteen quarters of an ordinary four year course. However, these are twelve-week quarters spaced by one week intermissions, and thus are quarters of a calendar year. In three calendar years the same ground is covered as in four normal school years. Since this theory of operation is discussed at length in an earlier paper of ours, we will not digress to develop it here.*

It will be observed that the outline places a strong emphasis on the fundamentals. There is plenty of mathematics and a lot of physics. Save for the first two terms, which are given to chemistry, physics carries straight on through every quarter. It takes the form of thermodynamics, fluid mechanics, and a bare introduction to aerodynamics. English is included, fundamentally, then for written and spoken expression. Economics, industrial psychology and engineering management are touched upon. Design work on the drafting board is developed most thoroughly. Along with design run courses in various types of shop application. These may very well come as credit allowance for industrial coöperative employment time, provided satisfactory grades are made in qualifying examinations. In any event, there is intended such close correlation between scientific theory and industrial practice, that motivation will be very high in both directions.

The course has nothing at all in it about steam engines or turbines. On this account, apparently our calling it a course in "Mechanical Engineering, strongly flavored with design, etc." has

* "College Level Training—War and Post-War," by C. T. Reid, a paper presented at the Texas Aviation Conference, A. and M. College of Texas, May 6, 1943.

SUGGESTED COLLEGE CURRICULUM FOR BACHELOR OF SCIENCE DEGREE IN AERONAUTICAL ENGINEERING

12 Quarters of 12 Weeks Each; 1 Week Between Quarters Fills Out Calendar Year; Duration Three Calendar Years

1	2	3	4	5	6	7	8	9	10	11	12
Chemistry 1	Chemistry 2	Physics 1	Physics 2	Applied Mechanics 1	Applied Mechanics 2	Kinetics of Machinery	Thermo-dynamics	Fluid Mechanics 1	Fluid Mechanics 2	Introduction to Aero-dynamics	Rule of Thumb Methods of Estimating Airplane Performance
English 1	English 2	Technical Report Writing	Speech	Economics 1	Economics 2	Engineering Scheduling and Cost Analysis	Engineering Manage-ment	Industrial Psychology	Internal Combustion Engines	Airplane Power Plant Installation Design 1*	Airplane Power Plant Installation Design 2*
Engineering Drawing 1	Engineering Drawing 2	Aircraft Detail Drafting*	Descriptive Geometry	Aircraft Layout Drafting*	Machinery Design	Strength Checking of Airplane Fittings*	Stress Analysis of Airplane Structures*	Airplane Structural Design*	Airplane Interior Arrangement Design*	Airplane Air Conditioning System Design*	Airplane Electrical System Design*
College Algebra 1	College Algebra 2	Trigo-nometry	Elective	Analytical Geometry	Differential Calculus 1	Differential Calculus 2	Integral Calculus	Differential Equations	Airplane Control System Design*	Airplane Hydraulic System Design*	Elective
Foundry and Forge Shop*	Machine Shop*	Sheet Metal Shop*	Aircraft Materials and Processes Laboratory*	Aircraft Lofting and Template Making Shop*	Aircraft Die, Jig and Fixture Shop*	Aircraft Ma-chinery and Manufactur-ing Methods Shop*	Materials Testing Laboratory	Structures Testing Laboratory	Mechanical Laboratory	Electrical Laboratory	Airplane Instrument Shop*

* Give credit for time in industry upon passing qualifying examination.

been criticized as a misnomer. Very well, let us call it something else. We do not wish to split hairs about terminology, although it does strike us that in the present world-wide range of job demands, a mechanical engineering course is more blame-worthy when it omits treatment of light-weight alloy materials and technique of product design than when it leaves out obsolescent steam engine theory and experiment. However, let's call our course: Aeronautical Engineering. It will deserve this name, judged by anyone's standards, when it runs far enough beyond the Bachelor's degree requirements here listed to accomplish by graduate study the complete training of a few stress analyses and aerodynamicists.

This is a heavy program with very few spaces left for electives. It is hoped that the curriculum committees may find in it the quantity and quality for a B.S. degree.

OTHER SUBJECTS SUGGESTED FOR ELECTIVE OR POST-GRADUATE STUDY

(Generally more than one 12 week course)

Advanced thermodynamics
Complex variables
Vector analysis
Electrical engineering
Advanced aerodynamics
Advanced propeller design
Advanced aircraft engine design
Aircraft instrument design
Indeterminate structures
Vibrational analysis of structures

Quality Control

A Field for the Mathematician

By BENJAMIN EPSTEIN

Associate Mathematician, Frankford Arsenal, Philadelphia

Within the past two decades, a significant change has taken place in industrial inspection. In 1924, Dr. Walter Shewhart of the Bell Telephone Laboratories published his investigations on the applications of statistical methods to the control of items produced by mass production methods. The general body of theory and its applications to production problems at the Western Electric Company have been treated in Dr. Shewhart's book published in 1931.* With the beginning of the present emergency there has been a marked increase in the application of statistical methods of quality control in British and American industries. The impact of war on hundreds of plants, which were suddenly required to fashion thousands of items held to close tolerances, made it imperative to control the quality of the product during its manufacture and to minimize the loss due to excessive scrap, inefficient inspection methods, unnecessary machine adjustments, and general waste of man-power. The old hit or miss methods of inspection were inadequate for the purpose. A scientifically sound system had to be introduced.

The basic principles upon which quality control of the product by statistical methods rests are these: The fundamental inspection is the process inspection. The aim of the inspection is to detect abnormal variations from the norm (as determined by statistical analysis of the data) during the process of manufacture and to take steps to eliminate the sources of trouble at once. Control is maintained by taking a succession of small samples at rationally spaced intervals during the process and requiring that the results of measurement or visual inspection remain within limits based on the prior history of the process. Wherever possible, actual measurements of dimensional quantities should be taken rather than the go-not-go type of measurement common in industrial establishments. If these main principles are followed, then the control chart will be an invaluable tool in the hands of the experienced engineer.

Up to this point it seems as if the problems involved in controlling the quality of products during the process of manufacture consist merely of recording data on charts and seeing to it that points continue to fall within certain control bands. If they fall outside these control bands, then the toolsetter or engineer goes to work and makes suitable changes to bring the

* W. A. Shewhart, "Economic Control of Quality of Manufactured Product," Van Nostrand and Company, Inc., New York, 1931.

process back into a state of control. The procedure appears to be cut and dried. What does this have to do with the mathematician?

The answer is simple enough.

The control chart is not a magic charm and does not automatically prevent the occurrence of trouble; the plotting of points on charts is not an end in itself, but is merely an aid to the engineering judgment. In practice it will be found:

(*a*) that it is a long hard job to attain a state of control—numerous difficult problems must be overcome in order to reach this stage;

(*b*) even if a state of control is attained, there will arise numerous instances in which there are departures from this state. Intensive research must be carried out in order to uncover the reasons for these departures.

In order to answer many of the questions arising under (*a*) or (*b*) it is often necessary to design carefully experiments which will uncover the reasons for departures from the normal state of affairs and sometimes yield other very valuable and pertinent information.

At the present time industrial engineers in general do not possess the knowledge and background in mathematics or physics to design experiments properly or to interpret the results of such experiments in the light of known statistical principles. They lack those elements of statistics which will at least give them facility in handling those problems which are encountered daily.

It is not difficult to enumerate some of the "normal" problems that confront the industrial engineer. Every time an engineer makes a series of measurements, he is dealing with some sort of population to which standard curve fitting and distribution theory could be applied. Whenever a change is made in a manufacturing procedure, whenever the product from one machine or one lot of raw material has to be *compared* with the product from another machine or another lot of raw material, he is dealing with the question of whether or not the differences observed are significant or just caused by sampling fluctuations. Whenever there is a marked connection among measurable physical quantities (*e.g.*, temperature, hardness, length, surface coating, etc.) then he is dealing with the theory of correlations. One could multiply these examples many times and still not exhaust all the possibilities of the application of *elementary* statistical methods to engineering problems.

The problems just mentioned are essentially routine in character. Yet the training of most engineers is inadequate for handling such problems. Under the circumstances it is hardly to be expected that they will be able to handle the more complex experiments which frequently occur in industrial work. They need the expert advice of the mathematician in order to solve such problems.

It is not uncommon to find the following sort of problem in practice:

Suppose that the functioning of an article A depends on the measurable quantities a, b, c, d. Suppose further that the values of a, b, c, d, satisfy the following conditions:

$$a_1 < a < a_2 \qquad c_1 < c < c_2$$
$$b_1 < b < b_2 \qquad d_1 < d < d_2$$

(a, b, c, d may be expressed in various units, *e.g.*, a and b might be lengths, c, grain sizes and d, weights). Then what combinations of values of a, b, c, d will give the best functioning of

article A? In order to answer this question one might employ a factorial design with $2^4 = 16$ combinations.* The analysis of variance would tell one whether or not changes in certain of the factors or combinations of factors would affect significantly the functioning of A. It is readily seen from this sort of example, how one might logically proceed to construct the best set of tolerances within which to maintain the product and to make a specification, possessing the highly desirable property that no article A possessing any combination of values of a, b, c, d whatsoever (a, b, c, d, lying of course, within specification limits) would give poor functioning.

The design of experiments in industry is a relatively new field and the opportunities for the mathematician are many. He can make a great contribution to the effectiveness of engineering, design, and research departments by:

(a) teaching the fundamentals of statistics to members of the engineering staff;

(b) developing statistical methods of quality control throughout the plant and teaching the methods to supervisory inspection personnel;

(c) using the factorial design of experiments and other modern experimental techniques to uncover significant causes of variation and analyzing the data thus obtained—such experiments sometimes lead to relatively pure research.

(d) applying the results obtained from well-constructed experiments to change designs or to alter specifications.

The greatest contributions in the field of quality control have been made by mathematicians and physicists. It is likely that this trend will continue, as long as engineers do not receive the theoretical training necessary to perform the non-routine investigations in this field. It is too much to expect mathematicians and physicists to go into the field in a wholesale manner. However, those scientists at present employed in industrial capacities or attached to research groups could render a signal service by aiding in the promotion of the use of sound statistical methods in controlling the quality of product or the designing and analysis of experiments.

* For the design of experiments, see R. A. Fisher, "Design of Experiments," Oliver & Boyd, 1935, Edinburgh and London.

Castings Design and Engineering Curricula*

By NORMAN F. HINDLE

Assistant Secretary, American Foundrymen's Association, Chicago

In introducing this paper, the author believes that it might be well to acquaint the reader with just what the foundry industry is. The foundry industry is the fifth largest in the United States and consists of approximately 4,500 individual producers employing over 750,000 people, which, in 1942, produced over 20,000,000 net tons of finished product valued in excess of $3,000,000,000.00. The products of the industry, namely, castings, are so varied in type, size, and metal used and are produced by such a variety of processes that no general statement can be made concerning them. We use them daily in our natural routine of life, but probably do not realize it to any great extent.

Types of Foundries

Producing plants are of two general types, the so-called jobbing and captive foundries. Captive foundries are owned and operated as part of a company and the products of such foundries usually are incorporated in the product of the company. Jobbing foundries are independent castings producers which sell their products to the user. Some foundries, especially the captive type, are quite large, several normally producing between 1,000 and 3,000 tons of castings daily, but when compared with the large plants of the country, even the largest foundry would be considered small. In normal times, the product of the larger jobbing foundries is sold within a radius of approximately 500 miles of the plant.

Foundry Practice and Engineering Curricula

Since the foundry or the metal casting industry is the fifth largest in the United States, why, then, have the metal casting processes in many instances been overlooked by engineers as a method of fabrication? Why have universities and colleges not given an emphasis to foundry products and manufacturing processes comparable with their place in the industrial picture? In the opinion of the writer, there are several answers, but space does not permit their enumeration. However, one of the reasons is that too many engineering schools have clung to teaching the so-called foundry courses as an art rather than a science.

From the beginning, "foundry," along with certain other courses, has been taught as a shop course. It became tradition that these courses taught the use of the hands and engineering schools went to industry to find men trained in a particular trade to teach such shop courses. These shop courses became manual training or vocational courses and many, though not all,

*Presented at the 50th Anniversary Meeting (M.E.), S.P.E.E., Chicago, June 18–22, 1943.

schools continued to regard them as such.

The time for such courses is past. Foundry courses should be established on an engineering basis with instructors who have an engineering training and background and occupying a place on the faculty in equal importance to other members. The courses should cover processes and products and should deal with the manufacturing processes in general, with the metals cast and their application, the properties available and some metallurgy, particularly that portion devoted to solidification.

Great Progress in Foundry Industry

Furthermore, there is not sufficient coördination between the teaching of foundry practice in shop courses and such engineering courses as strength of materials, mechanics, machine design and metallurgy. Shop courses in the foundry have improved in some engineering schools during the past few years, due partly to the aggressive attitude on the part of some instructors and partly to the activities of the Committee on Coöperation with Engineering Schools of the American Foundrymen's Association. The latter committee is believed to have had an important part in the improvement of the so-called foundry shop courses.

However, as a whole, few engineering schools seem to realize that more progress and improvement has been made in the casting of metals in the past 15 years than in the previous 75 years and revised their engineering curricula accordingly. This is not entirely the fault of the schools. Part rests on the industry itself. On the other hand, any suggestions on how the engineering schools and the foundry industry may coöperate to their mutual advantage will receive attention and consideration.

Any statement made here is not intended to convey the idea that the foundry industry desires foundry practice, design and application of cast products to be taught in engineering schools to the exclusion of all other processes and materials. Each material and process ultimately justifies its place in the industrial picture economically. However, the foundry industry *does* believe that its products and processes should be given the part in the curricula of engineering schools and colleges to which its place in the industrial picture entitles it.

One Field of Foundry Progress

To accomplish the rapid strides made in the past few years, hundreds of thousands of dollars have been, and are being, spent annually on research in the foundry industry to improve the quality and control of its products. Among the various lessons that have been learned, and concerning which a great deal of research is now being conducted, is that casting design is important to production.

In the past, foundrymen took great pride in the fact that they could produce almost any design. The founding of metals was an art. One foundryman has stated that he spent his entire life defeating the laws of nature. However, during the past 10 or 15 years, foundrymen have begun to realize that, while ability to cast any particular design might be fine from the art standpoint, it certainly is not from the cost, profit or quality standpoints. As a result, foundrymen have given more consideration to the design of castings and have emphasized the

need for coöperation between the engineer, patternmaker and foundryman before numerous engineering groups and in the literature.

The foundryman realizes that, as in other processes, design should take into consideration the vagaries of the process. He also realizes that coöperation between the engineer, patternmaker and foundryman will, in the end, result in a product that will not only serve its desired purpose best, but will result in castings being produced in the most satisfactory manner at the lowest cost.

Ultimate Cost Important

The previous statement does not mean that castings are necessarily a low-cost product, because cost is only relative and is dependent upon which method of fabrication can produce the best article most economically, not only from the viewpoint of production cost but from that of ultimate cost, which must take into consideration life of the part or assembly and its maintenance under its conditions of use.

Now, let us examine some of the reasons as to why coöperation between the foundryman, patternmaker and engineer are important in the design of castings. The author takes no credit for originality in any of the statements hereafter made. Any credit, should there be any, belongs to the foundrymen and engineers who have brought this knowledge to light and have contributed it to our store of knowledge. The writer has only attempted to coördinate some of the points.

Discussion of Casting Design Difficult

Because of the wide variety of castings manufactured and the inherent properties of the metals, both in the liquid and solid states, from which castings are made, and the methods and manufacture, a discussion of casting design in a general manner is difficult for several reasons. Among them is: (1) number of casting processes used, (2) the large variety of metals cast and (3) variation in processes of production.

Castings are manufactured by one of four general processes, namely, in sand molds, permanent molds, dies or centrifugally. The sand and permanent mold methods involve the introduction of the metal into the casting by gravity. In die casting, the metal is cast under pressure. In centrifugal casting, use is made of centrifugal force but the metal is introduced into the mold by gravity.

Evaluation of Casting Methods

Each method has its limitations and applications. These methods may be listed, in order of their versatility, as follows: (1) sand, (2) permanent mold, (3) die casting, (4) centrifugal casting. They might be listed, in relation to the number of metals cast by the process, in the following order: (1) sand, (2) centrifugal casting, (3) permanent mold, (4) die casting. In size of product possible by the process, they may be listed as follows: (1) sand, (2) centrifugal, (3) permanent mold, (4) die casting. In closeness of tolerances possible to be maintained, the methods may be listed as follows: (1) die casting, (2) permanent mold casting with centrifugal and sand castings about equal. Considerable progress is being made in the sand casting process in maintaniing closer and closer tolerances. In high repetitive jobs, extremely small tolerances are maintained.

Melting Processes

Cast iron may be melted in the cupola, air furnace, electric furnace, rotary, pulverized fuel-fired furnace or by the duplexing method. Steel may be melted in acid or basic open-hearth furnaces, acid or basic electric furnaces, converter, crucible furnaces, or induction furnaces, or by the triplexing process. Malleable iron is melted in air furnaces, cupola or by the duplexing process, the latter sometimes involving the use of electric furnace. Non-ferrous metals are melted in one of several type crucible furnaces, in the electric furnace or in the reverberatory furnace.

Metals

Metal used in casting manufacture include six general classes of gray iron based on strength, several types of chilled and white irons, over 70 types of alloy steels and many variations of plain carbon steels, at least three general types of malleable iron and seven general classes of non-ferrous alloys, within each of which there are several types. For example, the American Society for Testing Materials recognizes 23 classes of copper-base alloys, practically all of which are used in the manufacture of castings.

Casting Processes

Nothing has or will be said about the variations in the different casting processes and methods. However, it is sufficient to say that such variations exert an influence on the product.

The previously mentioned points are given merely to indicate that the casting of metals as a general subject is no easy task and to show that a general discussion of casting design is rather difficult.

The Ideal Casting

From the general standpoint, the ideal casting is one which can be: (1) Poured easily in all its parts, (2) cast without the use of risers or with not more than one (depending on the metal) located at the casting's highest point in the mold, (3) poured in such a manner that the last fluid metal will be in the riser and (4) cleaned with a minimum of difficulty.

A wedge standing vertically with the area of greatest thickness topmost, has all the attributes of the big-end-up ingot with a hot-top. Many are familiar with the huge amount of time, effort and money spent in the past and still being spent, in designing ingot molds for steel to secure greater yield and proper distribution of the constituents of the metal through directional solidification of the metals cast into it. This one point alone should be sufficient to impress the engineer with the importance of design in castings. Any foundryman would consider an ingot a simple casting. The great advantage of the casting process is that by utilizing it, metal can be placed where it is wanted and a good result can be secured, providing certain rules that govern the process are followed, particularly the directional solidification of the metal.

Prepraration of Design

In the preparation of design, after it has been conceived, it is advisable to make a sketch of the part, keeping in mind the following general rules:

1. Make the sections as nearly uniform in thickness as conditions permit.
2. Where section uniformity is not feasible, make a transition of

light sections into heavy ones gradually, never abrupt.

3. Visualize the casting in the mold and design it so that, as placed in the mold, it will solidify regularly and progressively from the lowest to the highest point.
4. Avoid designing castings so that heavy sections occur below lighter sections when the casting is in the mold, thus making adequate feeding of heavy sections difficult or impossible.
5. Design the casting so that it can be poured easily in all of its parts with a minimum number of risers or so that the risers, when required, are located at the highest point in the mold and so that the last fluid metal is contained in the riser.
6. Use fillets at junctions, especially in inside corners, but avoid making them so large as to produce excessively heavy cross-sections at the junctions. A good rule to follow is that the radius of the fillet should never be less than 80 per cent nor more than 120 per cent of the radius of the sections which it intersects.
7. Employ ribs where they help to avoid warpage or are needed for extra stiffness and can be used to lower weight and still not interfere with the ready preparation of the mold.
8. Where intersecting ribs or junctions of members result in undue concentration of metal with resulting hot spots, consider the advisability of staggering, or, in the case of large castings, the use of simple cores at the intersection to equalize cross-sections at the junctions.
9. Avoid the use of deep pockets in designs, as such pockets generally involve an undue increase in cleaning costs.
10. Aim to make the casting as simple a structure as conditions permit, investigating the possibility of using two or more separate castings, to be joined subsequently if a one-piece casting is highly complex and gives promise of lower overall cost if cast in parts.
11. Avoid the use of as-cast dimensional tolerances which are closer than necessary. Make sure, in a conference with the producer, that such tolerances as are specified can be met by the producing foundry.
12. Where lettering and similar markings are required, see that they come on a face or surface of the casting parallel or nearly parallel with the mold parting and in such a position as to impose minimum restriction to metal flow and proper progressive solidification. Some A.S.T.M. specifications state, "The resistance of a sand mold to the erosive effect of inflowing metal is aided by smooth mold surfaces. Cast identification marks are formed by making indentations on the face of the mold. For the prevention of small defects caused by dislodged particles of molding sand, there should be provided the minimum feasible number of cast identification marks."
13. Avoid the use of metal inserts, if possible. Such inserts should be avoided, especially where fusion between the insert and the

casting is absolutely essential (unless it can be guaranteed by the producing foundry), or unless the advantage gained is not offset by greater difficulties in production than the proper insertion in casting would entail.

14. When castings are exposed to view in the finished product, design them with simple flowing lines and with exteriors as free from unnecessary projections as conditions permit. Such precaution will make them more sightly in appearance.
15. Keep the size and weight of the casting and, hence the size of sections, as small as is consistent with adequate performance of its function.

Conference on Design

The above are some preliminary rules which the engineer may make use of in preparing his drawing. The next step in the procedure should be a joint conference with the patternmaker and foundryman to discuss the production procedure for the design. Constructive criticism of the design should be sought from the foundryman and patternmaker and, where possible, their suggestions on revisions to simplify the design with a view towards increasing the ease of production and, hence, decreasing production cost, be followed.

At this same conference, the engineer should explain to the foundryman the conditions that the casting must meet, where it fits into the total assembly and what functions it must perform. Such information gives the foundryman knowledge he can use in offering suggestions to the designer.

Considerations in Pattern Equipment

The patternmaker should be consulted concerning difficulties which may arise in the preparation of the pattern equipment, because type of pattern equipment and its construction exert an important influence on the production cost of the part.

Avoid Loose Pieces

The engineer should discuss with the patternmaker and foundryman the molding procedure with a view toward avoiding, for example, loose pieces in the pattern equipment. Loose pieces generally mean increased molding cost. Such loose pieces should be used only when the desired results cannot be secured by some other method.

Pattern Parting Line

Another point of interest to the patternmaker is the parting line. The engineer should design his castings in such a manner that it is possible to use pattern equipment with a straight parting line. Irregular parting lines generally increase cost because of either one of two reasons. If the castings are to be made as a production job, involving many thousands, it sometimes is possible to utilize irregular parting lines by using special flask equipment, but this involves additional cost. It may be possible, by the use of cores, to overcome this difficulty although again there is the increase in cost due to core box equipment and additional operations, such as baking of the cores, inspection procedures and possibly jigs for setting the cores in the molds, plus the operation of setting the cores themselves.

Pattern Draft

Of particular interest to the patternmaker is the amount of draft allowable in his pattern. Draft is the taper which must be allowed on all vertical surfaces of a pattern to permit its removal from the mold. Engineers should allow the use of as much draft as appearance of the casting and other factors, such as avoiding higher machining costs or when too much draft causes metal concentrations at points where proper feeding is impossible, will allow.

Ample draft on a pattern means easier molding. Usually, about 2° draft is a minimum allowance. However, in certain castings where considerable experience has been obtained and where thousands of castings of the same design have been produced, it is sometimes possible to reduce the draft to about 1°. If the casting can be made by machine molding, it is best to do it that way, as patterns for machine molding require minimum draft.

Core Considerations

The engineer should be interested in the number of cores to be required for his design. If at all possible, he should design his casting in such a manner, at least for small and medium size castings, that it leaves its own core in the mold. When this is not possible and core boxes are necessary, he must look for an increase in production cost. Large numbers of dry sand cores generally mean an increase in the number of core boxes, possibly dryers, which increases the pattern cost and, in addition, means the additional operations of making, baking and proper placing of the cores in the mold. The latter increases molding cost. Therefore, it is a good rule to design a casting in such a manner that as few as possible cores are necessary.

Core Support

Another point which the engineer should remember is that allowance should be made for adequate support of the cores in the mold. This is especially true in castings which must withstand pressure. If at all possible, the design should minimize the use of chaplets for the support of cores. This is because it is difficult to secure proper fusion of the chaplet with the metal.

Provide Clean-out Holes

In cases where it is necessary to use interior cores, which are nearly or entirely surrounded by metal, provision should be allowed for venting the cores and for cleaning them out after the casting has been made. Clean-out holes sometimes can be allowed which afterwards may be plugged either by a machining operation or by welding.

Use of Long, Thin Cores

The engineer should also keep in mind the ease with which the cores required in the casting can be removed. In structures where long thin cores are surrounded by heavy metal sections, it is extremely difficult to remove the cores from the casting. The difficulty is multiplied several times when the opening provided by the core is not straight. In such instances, the ferrostatic pressure of the liquid metal often is so great as to force the metal between the interstices of the sand grains in the core, thus creating a situation where the core becomes a mass of sand and metal. Under such conditions, naturally, cleaning costs will rise, sometimes entirely out of proportion to the remainder of the cost of the casting.

As previously stated, the above rules of design for castings are general and by no means inflexible. They represent a common sense approach, if taken into consideration by the designer, to minimize foundry difficulties in production, therefore, reducing casting costs and improving the product. They do not deal with strength possibilities in sections but they do somewhat take into consideration stress distribution. For example, in the joining of sections, the reason for the use of adequate fillets is self-evident because it has been proved many times by photoelastic analysis that sharp corners are points of stress concentration.

Metallurgical Problems Not Discussed

This discussion also has not dealt with the metallurgical phenomena involved for the various metals, as this is a field entirely different and time does not permit its discussion. The writer has definitely avoided the discussion of gating and risering, as this is a worry of the foundryman, except for the fact to point out that design is very much tied in with the location of risers for the reason that hot spots in the casting must be fed with adequate metal to take care of the difference in solidification rate between the hot spot and the normal sections.

Knowledge of Foundry Procedure Helpful

From the above, it should be quite evident that the engineer should have some knowledge of foundry procedure. He cannot be expected to have an intimate knowledge. He should at least have as much knowledge of foundry procedure as he has of other processes, such as welding and stamping. In designing parts to be made by these processes, the vagaries of them are taken into consideration. It is only fair that the foundry industry, being one of the largest basic industries in the United States, should have as much time given to it in the engineering curriculum as is required to give sufficient knowledge to the engineer concerning it.

Conclusion

In conclusion, the foundry industry acknowledges that the casting of metals is not the only method of metal fabrication. It also recognizes that cast metals are not the only engineering materials. The industry does, however, desire that its processes and that the design of its products be given the consideration in the engineering curriculum to which its place in the industrial picture entitles it. It feels that this has not been altogether the case in the past. However, it does hope that the future will see change in the attitude of those responsible for the engineering curricula toward giving the foundry industry and its products what might be termed an "even break."

As previously mentioned, this can be done by recognizing the fact, as some schools have, that the instruction in foundry courses no longer should be of a manual training vocational type but should have an engineering basis; that foundry courses should be taught by instructors with an engineering background who occupy a position on the faculty equal to instructors or professors in other courses; and by recognizing the fact that the work of the foundry teaching staff should be tied in with the work of those instructors teaching strength of materials, mechanics, machine design and metallurgy.

What Is the Engineering Profession?

By CHARLES F. SCOTT

Emeritus Professor of Electrical Engineering, Yale University

"What is the engineering profession; is it a profession at all?" This query is given serious significance by the professional standing of the man who made it—Vannevar Bush.

In presenting Dr. Bush for the A.I.E.E. Edison Medal a few weeks ago, Frank B. Jewett said of the one time professor and vice president of M.I.T., and later President of the Carnegie Institution of Washington, "As scientist, teacher, inventor, designer of powerful mathematical tools which have lightened the burden and expanded the possibilities of engineering generally, and as a distinguished director of scientific research, he has earned for himself not only a high place in the ranks of American scientists and engineers but likewise, and justly, the right to be the nation's scientific leader in this time of great national danger. . . . I never cease to marvel at a man who in days filled with such turmoil (the turmoil of the directorship of scientific research and development in a nation at war) can find the time and, above all, the philosophical detachment needed to formulate a state paper like the recent letter to Senator Kilgore on the problem of technological mobilization."

Five years ago Dr. Bush addressed the American Engineering Council on "The Qualities of a Profession." After reviewing law and medicine and teaching and their common professional elements he continued:

"Our principal concern is the engineering profession and we inquire, what is the engineering profession; is it a profession at all; and if it is will it develop into the full stature to which the importance of its work entitles it to aspire? It is relatively young. . . . Applying science in an economic manner to the needs of mankind is its broad field. Its disciplines are spread over all the sciences as they become thus applied, and embrace also portions of economics, law and business practice which are integral parts in the process of application. It is somewhat loosely organized as professions go . . . there is no body of codified principles which is accepted and applied by the profession as a whole. If there is no central organization which has as its creed the best service of the profession to the society of which it forms a part, then there will be in the end no engineering profession. . . .

"Out of this trend . . . should emerge a new profession with its own traditions and beliefs which is capable of managing prosperity so that it will be conducive to the health of a nation. . . . The impact of science is making a new world and the engineer is in the forefront of the remaking. . . . Certainly there never was a profession that more truly needed the profes-

sional spirit if the welfare of man is to be preserved."

Elsewhere Dr. Bush commented on the engineer: "What renders a man a member of his professional group? It is much more than the possession of special knowledge. The distinguishing characteristic is the possession of a philosophy and a point of view. The true criterion lies in the basis of motivation of the individual." It was with profound understanding and clear vision that Dr. Bush asked, Is Engineering a Profession?

But how is our engineering profession to develop into the full stature to which it is entitled to aspire? Each year S.P.E.E. has a new leader, experienced in science and engineering, in industry and education, and this year a leader experienced also in dealing with engineering organizations through chairmanship of E.C.P.D.—dedicated to "the enhancement of the professional status of the engineer" through "greater effectivenesd in dealing with technical, social and economic problems." President Doherty has "a philosophy and a point of view." In his initial keynote letter to each Society member, he asks that teachers take "a stronger part in building the engineering profession" as he finds "the engineering teacher to be in the key position. His responsibilities are very great . . . if the engineering profession is to come into its own with a new understanding of its inevitable responsibility to society, the engineering teacher must bring it there."

S.P.E.E., on recommendation of Robert E. Doherty, D. B. Prentice and C. C. Williams (its representatives on E.C.P.D.) is now concerned with engineering as a profession. The new activity is sponsored by Ivan C. Crawford, General Chairman of Coordinate Committees in Personal Development, who is cooperating with E.C.P.D.'S Committee on Professional Recognition of which the writer is Chairman. Dean Crawford in THE JOURNAL OF ENGINEERING EDUCATION, January and October 1943 issues, recognized the importance of the project to the engineering profession and proposes a study of "the methods employed by the colleges to develop an understanding and interest in those phases of engineering which supplement the technical." He also emphasizes the viewpoint that the professional aspects of engineering "should be brought into all courses incidentally by the instructor." He is further endeavoring to inform and interest engineering teachers in the "inevitable responsibility."

In discussing ways and means W. E. Wickenden recently suggested that each teacher picture to himself what a unified and professional motivated engineering profession might accomplish as compared with its present diversified units.

Surely if the teacher realizes the practical significance of Dr. Bush's professional goal, he will imbue his students with ideals and inspiration.

College Notes

University of Colorado.—Dean Herbert S. Evans retired on November 1, and was succeeded by Professor Clarence L. Eckel. Dean Evans has been with the University for thirty-eight years, coming to the University of Colorado in 1905 as Head of the Electrical Engineering Department. He became Dean of the College in 1919. He has been especially interested in engineering education and has been a member of the Committee for accrediting engineering schools. He was Vice-President of the American Institute of Electrical Engineers in 1931 and President of the Society for the Promotion of Engineering Education in 1932. In his twenty-four years as dean, the College has increased from 475 to 1060 students. Though Dean Evans was officially retired, he was immediately "drafted" for war work by the University to help with teaching in the Navy V-12 and the Marine M-3 curricula.

Professor Clarence L. Eckel joined the faculty of the University in 1914 and became Head of the Department of Civil Engineering in 1926. Besides his work in education, Dean Eckel has had considerable experience in the practice of his profession, for during his "academic vacations" he has worked for a number of engineering companies. He also shared the responsibility for the design of many of the University buildings in its two-million-dollar expansion program preceding the war.

Professor Warren Raeder has been appointed Head of the Department of Civil Engineering. He came to the University in 1926. Recently he has been in charge of the E.S.M.W.T. program for the University, which has trained about 5000 men and women. Last month he was elected President of the Colorado section of the A.S.C.E. for 1944.

L. B. Sutherland, professor of civil and architectural engineering at the University for twelve years, has left the staff to take a position with the C. F. Braun Manufacturing Company in Alhambra, California. He will direct research for the company, which manufactures and designs equipment for oil refining. Professor Leo Crandall has been appointed to fill the vacancy left by him.

John M. Cage, associate professor of electrical engineering, who came to the University in 1939, has accepted a position as head of the electronics section of the controller division of the Allis-Chalmers Corporation in Milwaukee. His work will be entirely in war projects and will deal with the designing and manufacturing of equipment in the field of electronics.

Sections and Branches

The ninth annual meeting of the **Allegheny Section** of the Society was held at the University of Pittsburgh on Monday, November 29, 1943. Sixty-seven registered.

At the afternoon meeting, presided over by Professor Frank H. Stiening, head of the Mechanical Engineering Department, University of Pittsburgh, Chairman of the Allegheny Section; Dean E. A. Holbrook, School of Engineering and Mines, welcomed the members and guests to the University.

The minutes of the Eighth annual meeting of the Allegheny Section held at the West Virginia University, October 16, 17, 1942, were read and approved.

The nominating committee presented the following names for officers for 1943–1944. These officers were unanimously elected:

Chairman, George A. Irland, Prof. of Electrical Engineering, Bucknell University.

Vice-Chairman, Douglas F. Miner, Westinghouse, Prof. of Engineering, Carnegie Institute of Technology.

Secretary, H. A. Shaffer, Asst. Prof. of Electrical Engineering and Drawing, Bucknell University.

Frank H. Stiening, Member of the National Nominating Committee, 1944.

An invitation was received from Bucknell University to hold the 10th annual meeting at that University in 1944. The invitation was unanimously and gratefully accepted.

At 4:00 P.M. the members adjourned from the general business meeting to attend one of four informal conferences on A.S.T. courses as follows:

1. Advanced Civil Engineering, L. C. McCandliss, *Chairman.*
2. Advanced Electrical Engineering, H. E. Dyche, *Chairman.*
3. Advanced Mechanical Engineering, J. A. Dent, *Chairman.*
4. Basic Engineering Subjects, Walter Turkes, *Chairman.*

The group (67 in number) reassembled for an informal dinner meeting at 7:00 P.M. at the University Club, Pittsburgh, Pa. Chairman, F. H. Stiening presided. Robert E. Doherty, President of the S.P.E.E., President, Carnegie Institute of Technology, spoke on the "Engineering Colleges and the Army Specialized Training Program." A condensed version of President Doherty's address follows:

To speak to this group about details of the actual working of the Army Specialized training program would be carrying coals to Newcastle, since most of you know more about the classroom problems presented by the Program than I do. I will say, however, that the Program has now reached full development and has attained a reasonably stable condition. There are about 140,000 trainees, and the monthly turnover is some 10,000 to 15,000. Of course, changing war demands may require changes in these numbers.

I happen to have two general connections with A.S.T.P. I am a member of the Advisory Committee to the Army Specialized Training Division and also Chairman of the S.P.E.E. Committee on the Army Specialized Training Program and the Navy College Training Program. I wish to speak briefly concerning the activities of these Committees and comment upon the effect of A.S.T.P. on engineering colleges.

The Advisory Committee, which reports to General Walter L. Weible, Director of Military Training, General Staff, has the following Personnel:

Isaiah Bowman, President, Johns Hopkins University.
K. T. Compton, President, Massachusetts Institute of Technology.
Robert E. Doherty, President, Carnegie Institute of Technology.
Clarence A. Dykstra, President, University of Wisconsin.
Guy Stanton Ford, Secretary, American Historical Association.
The Very Reverend Robert I. Gannon, President, Fordham University,
Ralph D. Hetzel, President, Pennsylvania State College.
Felix Morley, President, Haverford College.
John J. Tigert, President, University of Florida.
Ray Lyman Wilbur, Chancellor, Stanford University.

It was organized in January, 1943, when plans for A.S.T.P. were being formulated, and thus it was in position to offer counsel from almost the very beginning. The Committee holds quarterly meetings in Washington with General Weible, Colonel Herman Beukema, Director of the A.S.T. Division, Lieutenant Colonel Theodore Palmer, Deputy Director, and other staff officers, the most recent meeting having occurred on November 15 and 16. The subjects discussed include curricula, contracts, and certain matters of policy such as participation in athletics, administrative relationship between military and educational officers, publicity, etc. This Advisory Committee, of course, has no formal connection with S.P.E.E.

The S.P.E.E. Committee on A.S.-T.P. and N.C.T.P. was appointed at the annual meeting of the Society in June at Chicago. The personnel of the Committee of which I happen to be Chairman, is as follows:

F. L. Bishop, Secretary, S.P.E.E.
F. M. Dawson, State University of Iowa.
Gibb Gilchrist, Texas A. & M. College.
H. P. Hammond, Pennsylvania State College.
Charles E. MacQuigg, Ohio State University.
A. A. Potter, Purdue University.
Donald B. Prentice, Rose Polytechnic Institute.
Thorndike Saville, New York University.
B. M. Woods, University of California.

By request of Dean Joseph W. Barker, who as Special Assistant to the Secretary of the Navy is in charge of the N.C.T.P., the President of S.P.E.E. is a member of the Naval Advisory Educational Council and transmits to Dean Barker any recommendations of the S.P.E.E. Committee concerning the Navy Program.

As regards A.S.T.P., the Chairman of the S.P.E.E. Committee reports to Colonel Beukema, and through the Chairman the Committee cooperates

with the staff of the A.S.T. Division concerning improvements in the engineering phase of the Program. The Division has three branches, as follows: Facilities, with Colonel Blake R. Van Leer as Chief; Curricula and Standards, with Dr. Arthur L. H. Rubin as Chief; and Operations, with Colonel Stuart McLeod as Chief. The S.P.E.E. Committee is most closely associated with the Engineering Section of the Curricula and Standards Branch. Lieutenant Colonel Fred H. Pumphrey, Chief of the Engineering Section, has four competent assistants, all of whom are former faculty members of engineering colleges. One of them is well known to most of you—Major Douglas F. Miner, on leave from the faculty of Carnegie Institute of Technology. To date the S.P.E.E. committee has concerned itself with such matters as the revision of course outlines, the question of examinations, improvements in screening, the question of whether sufficient study time is available, and problems connected with negotiation of contracts. It has made a spot check on the question of whether the Program is too heavy in view of the limited time available. And more recently it has been very much interested in the morale of the trainees, concerning which unfavorable reports have been received from some campuses. One important reason for low morale is the unavoidable changes occurring in Army demands for specialized personnel. The trainees were originally given the impression that the Program was largely one of officer procurement, and hence they were naturally disappointed when opportunities for entrance into the Officer Candidate Schools were drastically reduced. It is our obligation, however, to help them to realize that though the demand for additional officers is now slight, this situation may change; and furthermore, that in any event the studies which the trainee is now following are improving his chances for advancement in the Army if he makes good, no matter what assignment he may be given initially. Another harmful influence upon morale is unguarded remarks that are reported to have been made by some instructors here and there in the Program. I feel confident that there are very few among us who would deliberately create any lack of confidence on the part of the trainee, and I know that on the contrary we shall all wish to use every opportunity to help the trainees maintain enthusiasm for their work and to convince them of its importance.

It is probably in order to say a few words about the effects of A.S.T.P. upon engineering colleges. More than ever, the military programs are focusing attention upon the importance of setting up clear objectives in any educational program and testing the students to determine whether such objectives have been achieved. I was much interested in what General Kutz said at the Chicago meeting of the S.P.E.E. In regard to the objectives of the training program in Ordnance. He likened them to a target in the center of which is a bull's eye, called "*must* know," surrounded by a circle labeled "*should* know," which in turn is surrounded by a circle "*nice* to know." The A.S.T.P. is being forced to a similar concentration upon what the trainees *must* know, as different from what it would be *nice* for them to know. Because the objectives of the Program were none too clearly stated at the outset, an attempt was

made to cover far more ground than could possibly be covered adequately in the time allotted, and the result has been a superficiality of treatment which is highly undesirable. Accordingly, course outlines are now undergoing careful revision. It is going to be increasingly necessary for engineering educators to devote attention to the same end in connection with the peacetime curricula. As you know, there is a S.P.E.E. Committee on Engineering Education after the War under the chairmanship of Dean H. P. Hammond of the Pennsylvania State College. This Committee has been very active, and I anticipate far-reaching and highly significant results from its study.

In conclusion, let me assure you that the officers of S.P.E.E. are doing their best to help in making A.S.T.P. effective by bringing to bear on the problems of the Program the experience and point of view of the people who are actually doing the job on the campus.

R. C. GORHAM,
Secretary

Civil Engineering Division, Chairman L. S. LeTellier presided at the meeting on June 19, with 75 in attendance. Lt. Col. Humphrey, War Department, spoke on "The Army's Specialized Training Program in Civil Engineering." Ray Paustian showed a colored movie of the manipulation, disassembly and adjustment of an Engineers Level. R. B. Wiley, Chairman of the A.S.C.E.'s Committee on Engineering Education, reported concerning proposed cooperation between his Committee and this Division on the subject of educating civil engineers. S. T. Carpenter in reply offered many pertinent questions and urged that an immediate factual study be made. After full discussion it was moved that this problem be left to the Executive Committee of the Division, with power to take appropriate action.

The offer of W. L. Malcolm to mimeograph for distribution to the C. E. Division copies of the reports of Professors Wiley and Carpenter was accepted.

Reports were received from Chairman E. W. Carlton of the Committee on Surveying and Geodesy, and from Chairman H. E. Pulver of the Committee on Construction Engineering Education.

J. S. Dodds, as Chairman of the Nominating Committee, presented the following nominations for 1943–44:

Chairman, D. S. Trowbridge, New York University.
Editor, H. E. Pulver, University of Wisconsin.

New Members to serve until July 1946.

Secretary, H. M. Dibert, W. & L. E. Gurley, M. I. Evinger, University of Nebraska.

Upon motion the nominations were accepted and the men declared elected.

At a meeting of the Executive Committee on June 20, 1943 the following resolution was adopted:

RESOLVED, that the offer of cooperation of the American Society of Civil Engineers, as embraced in certain resolutions of its Board of Directors, and as presented to the Division by the Committee on Engineering Education of A.S.C.E. on June 19, 1943, is hereby accepted; and that the Executive Committee of the C. E. Division is hereby authorized to appoint a Committee to confer with the Committee on Engineering Education of the A.S.C.E. for the purpose of preparing a plan of coopera-

tion; and that this Committee report to the Executive Committee as soon as may be practical its proposed plan of cooperation, for consideration and appropriate action by the Executive Committee.

The **Michigan College of Mining and Technology Branch** of the Society was organized November 26, 1943, at Houghton. The following were elected officers: Chairman, L. A. Rose, department of languages; Vice-Chairman, F. L. Partlo, associate professor of mathematics and physics and academic coordinator of Army programs; Secretary, Chester Russell, associate professor of electrical engineering and acting head of the department. In accordance with the provisions of the brief constitution then adopted, these officers named the following committees: membership—C. T. Eddy and C. H. Baxter; program—W. A. Longacre, George Machwart, and Ella Wood; post-war plans—A. P. Young, H. L. Coles, F. L. Partlo, and F. H. Hanselmann. The last-named committee works closely with the college's committee on post-war education and placement.

The first regular meeting, after news was received January 10 of the acceptance of the Branch by the Society, was held on January 20, with 29 members and guests present. Professor Partlo, the main speaker, discussed "Post-War Academic Problems." Professor Young reported on the projects undertaken by his committee and offered certain recommendations. An hour's enthusiastic open-forum discussion concluded the meeting.

The occasion for a brief special meeting on February 1 was the resignation of Professor Russell as secretary. The Branch passed a resolution of regret, and elected Professor Longacre to the office.

The next regular meeting is tentatively scheduled for March 7. One of the speakers will be Dean James Fisher, a member of the Society since 1899, who will explain the relationship of the E.C.P.D. and the S.P.E.E.

The Winter Meeting of the **Middle Atlantic Section,** S.P.E.E., was held on Saturday, December 4, 1943 at Manhattan College, New York City. The total attendance of the meeting was 130, which included 119 men and 11 women. Registration for the meeting took place at 11:00 a.m. and was followed by a general social hour and inspection of the campus and buildings. Luncheon was served in the dining rooms of the College at 12:30 p.m.

Chairman of the Section, Hale Sutherland, Lehigh University, presided, and introduced Brother A. Victor, President of Manhattan College, who extended a very gracious welcome to the Section and hoped that our visit to the College would be both interesting and profitable. He stressed the importance of various meetings dealing with engineering education, particularly in these times of great changes. He pointed out the importance of social and economic problems in our engineering world and emphasized the fact that the engineer of the future must take a larger and larger place in social and economic fields. He urged the extreme importance of humanistic studies in our scientific curricula. He advocated a well planned educational program which would include the regular four year basic college work and in addition a carefully planned postgraduate program. He stressed the importance of this postgraduate program in which a chance is given for the young engi-

neers to specialize in various fields of engineering and human relations.

The minutes of the Spring Meeting held in May 1943 were approved as published in the S.P.E.E. JOURNAL. The Treasurer reported a balance of $292.44 on hand as of December 4, 1943. At the May meeting of the Section a Nominating Committee was appointed to present candidates for the officers for the year 1944. The Chairman of this Committee, Dean Stanley Morehouse of Villanova, presented the following candidates for office: Chairman—J. Harland Billings, Drexel Institute of Technology; Vice-Chairman—J. Stephen Tracy, College of the City of New York; Secretary-Treasurer—Frank D. Carvin, Newark College of Engineering. There being no further nominations for officers, the above slate was declared elected as officers for the year 1944.

Following the Business Meeting of the Section, papers on the general topic of education in engineering were presented. The first paper on the subject "Education in Engineering for Public Service" was presented by the Honorable Arthur V. Sheridan, Commissioner of Public Works, Borough of the Bronx, New York City.

The general subject matter of Dr. Sheridan's paper dealt with the increasing importance of engineering in our social life and particularly in its relations to public service. He claimed that the engineer is becoming more and more the least dispensable servant in society. If our educational program is real, it should provide a better society; it should tend to prevent wars; and should make men good as well as fit for their jobs. Education should not be a means of independence, but rather it should stress man's dependence on society. He stressed the fact that we should discourage the tendency to specialize in our undergraduate curriculum. This curriculum should be kept extremely basic and have a well drawn balance between scientific and humanistic subjects. The engineer must be an administrator of society and must develop leadership in order to prevent a misuse of science. He claimed that the great destruction in modern warfare is directly a misuse of science and stressed the fact that in our future world we must begin to lead in order to prevent a reoccurrence of these things.

In his paper he anticipated an increasing amount of regulations on our daily activities by the Government. He claimed that we are rapidly approaching a socialized state. We should recognize this fact, and the engineer should take his place in this development. If he doesn't, the development will go on anyway and will be definitely under the direction of non-engineering people. In particular, problems in public service demand accurate technical knowledge, but they also demand a definite humanistic viewpoint. Work for public service definitely requires a philosophical, legal, social and technical background.

As a means of accomplishing this program, Dr. Sheridan suggested the following procedure:

"A step toward the accomplishment of the ends referred to might be found in the following educational program: A basic course—consisting of a thorough training in mathematics, the pure and applied sciences, fundamentals of engineering theory applicable to all branches of engineering and selected studies in the humanities—leading to the degree of Bachelor of Engineering. This would enable the graduate of such basic course to seek

immediate employment in technical and other fields of activity where educational, but not professional, backgrounds are essential. For those seeking professional status, additional scholastic study covering the specific application of science and engineering principles to various forms and types of engineering, together with further investigation of the humanities, including special reference to administrative law and to codes of ethics and practice involved in the work of a professional practitioner, or the equivalent experience and knowledge, might be a minimum requirement for the designation of Civil or Professional Engineer to be acquired through state examination and registration. This would approximate an internship or apprenticeship of perhaps two years. Further professional postgraduate study or experience in selected engineering work could then be required for specialist designations such as mechanical or electrical engineer or perhaps a doctorate in these subjects."

Dwayne Orton, Director of Education, International Business Machines Corporation, Endicott, New York spoke on "Education in Engineering for Industry."

Starting with a definition of science as man's conquest of natural resources, Dr. Orton stressed the need of a definite balance in education between scientific knowledge and a knowledge of human relation problems. He stated that no class or section can live within itself alone, but must coordinate its special interest with the general interest of the group. Industry must think in terms of the overall needs of a people and not in terms of special interest. He pointed out the social implications incident to ownership of industry.

In regards to engineering in industry he stated that engineering is the heart of industry, while education is its life blood.

In planning educational curricula of the future we must definitely balance our professional with humanistic subjects. He seemed to think that in general a two year program covering general education followed by a two year program of basic professional work should serve as our basic college training leading to a Bachelor's degree. At the end of this period industry and public works must take a direct interest in the future professional development of the engineering graduate. This should be done through postgraduate training both in industry and in college—the training being handled in the place best fitted for the particular conduct of the program in question. This would require a very close tie-up between industry and our colleges.

The general trend of the papers of the various speakers of the afternoon dealt definitely with the balance between scientific engineering training and humanistic training. Following the formal presentation of the papers, a discussion period of over an hour developed. As in many previous meetings, the main topic of our discussion was the time element involved. Most educators are definitely troubled with the problem of adding more and more humanistic subjects to our already overcrowded curricula. Considerable discussion hinged upon the relative merits of the four year program as against five and six year programs. It was generally agreed that in the basic four year program very little can be done to increase the humanistic character of the curricula. It was felt that the program now given has a fair balance between scientific and humanistic subjects. The consensus of opinion seemed to be that additional subjects in the humanistic

phases of society as well as advanced scientific studies should be the proper function of the graduate school.

The afternoon session adjourned at about 4 p.m. and dinner was served on the campus at 5:30 p.m. After partaking of a delicious dinner, the membership was treated to an excellent and well delivered address by Brother C. Edward, Vice-President of Manhattan College.

Brother Edward in general spoke of the engineer as a man. In his talk he stressed the importance of education in engineering to consider the welfare and the management of the men as well as their scientific activities. He pleaded for the development of the student as a whole and not simply his intellectual development. He claimed that a pure intellect is a monstrosity. He criticized our so-called code of ethics as a classification of man's vices instead of a code to develop his moral responsibilities. He pleaded for real culture in education and not that type of culture we find as "what the butcher would have if he were a surgeon."

Brother Edward's talk was very well received and was an exceedingly fitting conclusion to a very pleasant day spent at Manhattan College.

In closing the meeting Chairman Sutherland expressed the thanks of the Section to the officers of Manhattan College and to the Committee on Arrangements headed by Brother A. Leo for their excellent hospitality. The meeting adjourned at 8 p.m.

FRANK D. CARVIN,
Secretary

The next meeting of this Section will be at the Radio Corporation of America, Camden, N. J., probably on May 6, 1944.

The **Physics** conferences were held jointly with the American Association of Physics Teachers. Many national officers and members of the Association attended the conferences and contributed to the program. The physics program opened on the morning of Friday, June 18, with a conference on "Curricula Leading to Degrees in Engineering Physics," including the following papers: "The Curriculum in Engineering Physics at the University of Maine," C. E. Bennett, University of Maine; "Growth and Changes in the Engineering Physics Curriculum at the University of Illinois," P. G. Kruger; "Requirements of Industrial Physicists," G. E. Ziegler, Armour Research Foundation. The papers acquainted the audience with features of the organization of this comparatively new type of engineering curriculum, the students it has attracted, and the demands of industry for the type of training it affords. In the discussion of this conference H. L. Dodge, University of Oklahoma (on leave), presented a resolution adopted by the War Policy Committee of the American Institute of Physics, of which he is a member, urging cooperation between the American Association of Physics Teachers and the S.P.E.E. in approaching the problem of the development of engineering physics as a recognized curriculum in engineering colleges.

The second physics conference held Friday evening assumed the form of a symposium on the question: "How can the Engineering Physics Course Best Serve the Engineer?" Representative points of view were presented as follows: for Physics, by J. W. Woodrow of Iowa State College; for Civil Engineering, by W. C. Huntington, University of Illinois; for Electrical Engi-

neering, by T. J. Higgins, Illinois Institute of Technology; for Mechanical Engineering, by M. F. Spotts, Northwestern University. The concluding paper in the symposium, by G. P. Brewington of the Lawrence Institute of Technology, was entitled "Methods Found to be Applicable in Increasing the Efficiency of Learning in Sophomore Physics." This program stimulated a long and profitable discussion.

Saturday noon the physicists packed a private dining room of the Lawson Y.M.C.A. to hear L. W. Taylor, President of A.A.P.T., talk on "Physics Teachers and the War."

The speakers for the third conference, held Saturday afternoon, were all members of the War Policy Committee of the American Institute of Physics. Their program consisted of the following papers: "The Work of the War Policy Committee of the American Institute of Physics," by P. E. Klopsteg of the Central Scientific Company of Chicago; "Contributions to the Training Programs of the Armed Services. Post-War Planning for Physics," by R. C. Gibbs of Cornell University; "The Physics War Front in Washington," by H. L. Dodge, Director of the Office of Scientific Personnel, National Research Council. This group of papers was concluded with a discussion by K. T. Compton in which Dr. Compton included some observations he made on a recent trip to England. Following the papers, the members of the War Policy Committee, including H. A. Barton, sat as a round table to discuss problems of physics war policy and post-war policy at the request of those in attendance at the conference. The tenor of the entire program was dominated by the evidence of the increasing premium on working knowledge of physical principles and of the distressing shortage of manpower in physics. A renewal of the discussion of curricula in engineering physics, the subject of the first conference, resulted in the appointment of committees in both organizations to study the problem. (Minutes of Council Meetings, June 18–20, 1943, JOURNAL OF ENGINEERING EDUCATION, Vol. 34, No. 1, Pp. 15.)

A group of papers concerned with "Physics for the Armed Services," presented Sunday morning, comprised the final conference. The papers, replete with new suggestions, were the following: "Physics for Naval Aviation Cadets," by L. I. Bockstahler of Northwestern University; "The War Training Program in Meteorology," by H. R. Byers of the University of Chicago; "The Science Program in the Secondary Schools: Its Importance in the War Effort and the Post-War Adjustment Period," by K. Lark-Horovitz of Purdue University.*

The success of the conferences is to be attributed in no small part to the efforts of C. J. Overbeck, Secretary of the American Association of Physics Teachers, and P. L. Copeland in charge of local arrangements.

JAMES G. POTTER,
Chairman

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* "Problems of a Signal Corps War Training Program in Communications," by P. G. Andres of Illinois Institute of Technology.

Necrology

Joseph F. Oesterle, a member of the department of Mining and Metallurgy at the University of Wisconsin died Friday, December 17th at the age of 55 years. He had been ill only a short time and his death is keenly felt by his many friends and close associates. Professor Oesterle was born in Philadelphia in 1888 and secured his early education in that city. In 1913 he received the degree of B.S. from the University of Wisconsin. He served as a metallurgist with the Pennsylvania railroad until 1916 and then went to Gary, Indiana, as a metallurgist for the Illinois Steel Company. In 1918 he enlisted in the armed service of his country. After his discharge he served as Associate Physicist in the Bureau of Standards, Metallurgical Division. In 1921 he returned to the department of Mining and Metallurgy of the University of Wisconsin, where he carried out extensive investigative work on the viscosity and sulphur solubility of blast furnace slags. Several publications of the above work were made by the A.I.M.E. He received the degree of Ph.D. in metallurgy in 1929. He rose from the rank of Asst. Professor through Associate Professor to full Professor and in 1940 was appointed chairman of the department of Mining and Metallurgy at the University.

In 1922 he married Helen Shaeffer at Altoona, Pennsylvania. He is survived by his wife and five children; David, Joseph, Ellen, John, and Mary Frances.

Professor Oesterle was a tireless worker. He was associated with many of the national professional societies and belonged to the following: American Society of Metals, American Institute of Mining and Metallurgical Engineers, American Foundrymen's Association, Society for the Promotion of Engineering Education. He often served as chairman on important committees connected with these societies.

Professor Oesterle was an active leader in the Boy Scouts of America work in the Wisconsin Area and was awarded the Order of the Silver Beaver by that organization in recognition of his efforts in that direction. He was a third degree member of the Knights of Columbus and took an active part in the boy work of the local council.

In addition to his many other activities, Professor Oesterle found time to act as Consulting Metallurgist for a number of neighboring companies for the last several years.

The Measurement and Guidance Project in Engineering Education

By K. W. VAUGHN

Director, Project Office

Introduction

The Measurement and Guidance Project in Engineering Education is a cooperative research project instituted for the purpose of studying examination procedures appropriate for colleges of engineering. The Project is sponsored jointly by the Engineers' Council for Professional Development, the Society for the Promotion of Engineering Education, and the Carnegie Foundation for the Advancement of Teaching, each organization acting through its respective agency for test research.

For a number of years, the S.P.E.E. and the E.C.P.D. Committees on Student Selection and Guidance have conducted researches into the effectiveness of various types of examinations for selecting engineering students. These committees have also made significant progress in discovering and applying suitable guidance methods for high school students who intend to undertake engineering study. It is evident from these committee reports, some of which have appeared in this JOURNAL, that there is an increased interest in and need for dependable examinations for selection and guidance purposes in colleges of engineering. Recognizing the need for more definitive studies of such examinations, the S.P.E.E. and E.C.P.D. Committees on Student Selection and Guidance jointly applied to the Carnegie Foundation for financial support and assistance in the conduct of cooperative researches. This proposal resulted in the organization of the present project.

The Carnegie Foundation has long been interested in the efforts of educators to improve the educational process in engineering colleges. As early as 1917 the Foundation financed a study of engineering education which, like the present one, was sponsored by a joint committee of the national engineering societies.[1] Since that time, the Foundation has sponsored and supported many studies of collegiate education, several of which have been concerned directly or indirectly with engineering education.

In 1936, with the assisting sponsorship of four university graduate schools, the Foundation inaugurated the Graduate Record Examination—a series of objective examinations constructed for the purpose of analyzing collegiate achievement. The success of this group of tests under an increased sponsorship has pointed the way for profitable researches which

[1] Reported by Charles R. Mann, "A Study of Engineering Education," The Carnegie Foundation for the Advancement of Teaching, *Bulletin No. 11*, 1918, 139 p.

are now being conducted all along the college curriculum.

Aims of the Project

The general aim of the present project is to discover the effectiveness of certain types of objective examinations designed to assist in the selection and guidance of engineering students. It is hoped thereby to provide college administrators and teachers with suitable instruments and methods for adjusting more adequately the engineering student to his initial study in the college of engineering.

Within this general purpose, there are six specific objectives as follows:

(1) To develop a battery of objective tests (*The Pre-Engineering Inventory*) expressly designed to discover in the background of individual students at the time they begin engineering study certain abilities prerequisite to success in the engineering curriculum;

(2) To develop a battery of achievement examinations designed to incorporate both the tool and conceptual materials characteristic of the pre-specialization phase of the engineering curriculum;

(3) To determine the efficiency with which individual test scores (and various combinations of test scores) derived from the *Pre-Engineering Inventory* predict student success during the initial year of the engineering curriculum;

(4) To validate the battery of achievement examinations by the appropriate subjective and objective methods commonly applied to such examinations;

(5) To report all findings to the cooperative institutions, the S.P.E.E. and the E.C.P.D. with concrete suggestions as to how these findings may have implications for the guidance of beginning engineering students; and

(6) To cooperate wherever possible with the technical training programs of the several branches of the United States Armed Services.

At the time of this writing, all of the above objectives with the exception of Number 4 have been at least partially realized. The experimental form of the Pre-Engineering Inventory has been constructed and administered to more than 3,000 entering students of engineering. The revision of this battery is now well under way and the revised forms will be available for use with freshman classes entering in June of this year. The achievement examinations, now in process of construction, are scheduled for completion during the late summer. The Project Office is also completing researches into the effectiveness of the Pre-Engineering Inventory results for predicting success in A.S.T.P. courses. These studies were sponsored by the Army Specialized Training Division and represent, in part, our cooperation with that Division. All of the cooperating institutions have received reports of preliminary testings and final reports will be made as soon as the results of our studies are available.

Participating Institutions

In order to carry out the above plans, it was necessary to secure the cooperation of a number of colleges of engineering willing to participate in the Project. Since the nature of the undertaking and the funds available for it placed distinct limitations on the number of institutions that could be included, it was important that the cooperating institutions represent as adequately as possible different geographical areas, types of institutions, and curricular organizations. The

institutions now participating in the study are as follows:

California Institute of Technology
Carnegie Institute of Technology
State University of Iowa
Massachusetts Institute of Technology
University of Michigan
Newark College of Engineering
Northwestern University
Rose Polytechnic Institute
North Carolina State College of Agriculture and Engineering
University of Tennessee
University of Texas

It cannot, of course, be argued that the above institutions are completely representative of colleges of engineering in general, but there is sufficient diversity of geographical distribution, type of institution and breadth of curricular organization to be satisfactory for research purposes. While the Pacific Coast and the Rocky Mountain areas are least adequately represented, the Middle West, South, and Eastern institutions are represented by colleges of engineering of several different types. The privately-endowed institution, the state university, the technical institution, and the urban college of engineering are all represented in our studies.

It should be pointed out that while the sample of institutions included in the study was definitely planned, the institutions chosen were selected as being representative of a general type of institution and not for purposes of evaluating these particular institutions. The Project is in no way concerned with appraising formal entrance standards or achievement in the various colleges of engineering participating in the study.

All reports of test results are confidential in nature and the final research reports will be organized in such a manner that the cooperating institutions will be able to identify only the results for their own college of engineering in these reports. Light thrown on institutional status is incidental to the Project researches and must be sought by the institutions themselves, although the Project Office renders all possible services and advice in follow-up studies in which any participating institution is interested.

Organization of the Project

The agreement entered into by the agencies sponsoring the Project provided for the establishment of three major committees. These are designated as the Advisory Council, the Consultant Committee, and the Measurement Committee. In addition to these formal committees, the Project cooperates wherever possible with those committees of the S.P.E.E. and the E.C.P.D. whose activities are related to the activities of the Project.

Advisory Council

The functions of the Advisory Council are to establish the general policies of the Project, to maintain general supervision over its activities, and to appraise the work of the Project in the light of its objectives. This committee includes the Chairman of the E.C.P.D., the President of the S.P.E.E., the chairmen of the E.C.P.D. and S.P.E.E. Committees on Student Selection and Guidance, and representatives of the Carnegie Foundation. The members of the Advisory Council are as follows:

Robert E. Doherty, *Chairman*,
S.P.E.E., Carnegie Institute of Technology.

Everett S. Lee, E.C.P.D., General Electric Company.
Allan R. Cullimore, E.C.P.D., Newark College of Engineering.
R. L. Sackett, S.P.E.E., American Society of Mechanical Engineers.
W. S. Learned, Carnegie Foundation, Carnegie Foundation for the Advancement of Teaching.
K. W. Vaughn, *Executive Secretary*, Carnegie Foundation, Project Office.

The Consultant Committee

The Advisory Council is assisted by a Consultant Committee composed of prominent engineering educators whose training and experience particularly qualify them for assisting in the determination of the Project policies. This committee also reviews the examination procedures employed by the Project. The names of the present members of this committee are listed below:

A. R. Stevenson, General Electric Company.
B. M. Woods, University of California.
B. R. Teare, Carnegie Institute of Technology.
R. H. Frazier, Massachusetts Institute of Technology.
H. S. Rogers, Brooklyn Polytechnic Institute.
Francis M. Dawson, State University of Iowa.

The Measurement Committee

The Measurement Committee is composed of one representative from each of the cooperating institutions. The members of this committee are primarily concerned with developing examination materials, working with the subject-matter specialists in their respective institutions, and coordinating the work of these institutional groups with the work of the Project Office. The members of this committee are as follows:

California Institute of Technology, L. W. Jones.
Carnegie Institute of Technology, J. B. Rosenbach.
State University of Iowa, John M. Russ.
Massachusetts Institute of Technology, T. P. Pitre.
University of Michigan, A. D. Moore.
Newark College of Engineering, F. N. Entwisle.
North Carolina State College of Agriculture and Engineering, T. W. Wood.
Northwestern University, F. G. Seulberger.
Rose Polytechnic Institute, R. K. Strong.
University of Tennessee, Cecil Camp.
University of Texas, Carl J. Eckhardt.

The Measurement Committee held its initial meeting at the Hotel Shoreland, Chicago, on January 14–16, 1944. At this meeting the committee outlined the objectives and content of the achievement examinations and laid plans for their completion.

The Project Researches

We hope to go far beyond the test-construction functions of the Project and to seek more definite answers to several of the fundamental questions which have troubled engineering educators for many years. Since many of our researches are spread over a front much broader than heretofore attempted, we can expect to obtain more definite results than those ordinarily obtained from institutional researches or researches in which only a few institutions were represented.

Few, if any, previous research projects have been afforded as adequate an opportunity to study the relationships of student ability and success in the engineering curriculum as that provided by the present project. The accelerated college programs, the technical training programs of the various branches of the Armed Forces, and the pressing need for post-war planning all increase in geometric ratio our opportunity to study certain factors influencing success in the engineering curriculum.

While the objectives of the Project listed in a preceding section outline our activities in general, these statements are not sufficiently inclusive to describe all of our projected researches. Perhaps the simplest method of describing these researches is to list a number of the questions which will be considered in our studies. Some of the more important of these questions are as follows:

(1) Are there particular subject-matter patterns of high school preparation which influence success in the engineering curriculum?
(2) What type or types of examinations are especially valuable for predicting success in the engineering curriculum?
(3) What reliance can be placed in examination results for predicting success in the engineering curriculum?
(4) Are there distinctive types of engineering students which can be identified on the basis of entrance test results?
(5) Are the interests and hobbies of beginning engineering students related to student ability and achievement?

We recognize that we cannot offer conclusive answers to all of the above questions, but our efforts can at least throw added light on many of the problems inherent in these questions. We hope by thus identifying and carefully studying these and related problems that this concerted attack on the guidance problems of engineering education will prove highly profitable not only for those institutions participating in the Project, but for engineering education in general.

Letter to the Editor

DEAR MR. EDITOR:

The January number of the JOURNAL OF ENGINEERING EDUCATION is especially interesting to me in that it so clearly shows a tendency which I fear will be all too prevelant during the years to come after the war. This is the tendency in schools of engineering to belittle and stifle any general collegiate non-professional education in the attempt to get more and more engineering specialization into the standard four year course.

For twenty-five years we engineers have been paying lip service to the need for the young engineer to have training in general subjects. But try to get time for such training in the ordinary year course and you find faculties saying,

"Sorry it is impossible; Our chief competing engineering school gives more advanced work in engineering during the first years of the course. If we require any history or philosophy, or psychology, or literature the students will all go to the competing engineering school where they can put all their time into the mathematics, physics, and drawing which are basic to engineering. Let's put some history and philosophy into the 5th year when the student is mature enough to really understand their implications! Of course there won't be many students in the fifth year but at least we will keep our four year enrollment."

Never have I happened to see the difference between lip service and the proposed actual practice better exemplified than in your January issue.

First as to the lip service. On page 379 Mr. Yarnell says, "so should we engineers be planning well ahead in our educational field particularly as it relates to engineers' responsibility in civic affairs." Page 381, "In 1940 were the engineering faculties . . . conscious of the inadequacy of freshman preparation in United States history?" On page 381 the committee on post-war planning reiterates the 1934 words of Charles F. Scott, "An undergraduate course should equip wholesome and qualified youth with a basic acquaintance with science, familiarity with engineering methods, and an appreciation of social relations." On page 443 Gano Dunn, "If an engineer's training neglects the great human mirrors of history . . . his career as an engineer is limited."

These are all brave words. We read them with appreciation and approval. But when it comes to an actual Engineering Curriculum what do we do? Turn to page 410 and study the proposed curriculum in construction engineering. In the whole course of four years 25 hours a semester for 8 semesters, a total of 200 semester hours, there is allowed not one single hour for history, literature, sociology, or philosophy! It is true that 9 hours of English composition and 6 hours of economics are provided but both of these are rightly considered as tool courses rather than subjects that give a liberal and enlightened outlook. Granting for the moment that the English and the economics are outside the engineering field, every other bit

of the 200 hours is in the field of science and specialized training.

It seems to me perfectly ridiculous to require students to do 200 semester hours for a bachelors degree. Twenty five hours of work with high quality cannot be done if a "senester hour" is to mean the ordinary amount of outside study to which we are accustomed. And it seems to me even more tragic that these students are to be completely isolated from all human relationships for 4 years.

The author does suggest among the possible options of the 5th year (but not even dignified by a number of hours) that as a last resort the student might elect languages, history, and liberal arts subjects.

But by turning to pages 367 and 374 we see that about 49,000 students are in 4 year courses and about 2700 in courses beyond the four years, roughly 5%. Thus this particular program evidently assumes that 95% of the students will get very little if any of the so-called broadening subjects in their college education.

Of course this particular program has not been adopted so far as I know at any reputable engineering school, but the author maintains (page 409) that it is "based on some of the existing courses in civil engineering."

I venture to hope that in the years to come the engineering faculties will resist the temptation to crowd their curricula with technical subjects, and will require a reasonable part of the ordinary four year course, say 10%, to be spent in subjects that have nothing to do directly with engineering—history, aesthetics, political science, sociology, literature and philosophy.

It is perfectly evident that such a program will cut out 10% of the advanced engineering subjects which could replace these cultural subjects; but for myself, I am in full agreement with those engineers like Mr. Yarnall and Mr. Dunn who continually tell us, every chance that they get that we shall do well to give some breadth of training rather than all technology.

Yours very truly,

PHILIP C. NASH

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